Ground Water Report W 16

1963

Geology and Hydrology of the Mercer Quadrangle, Mercer, Lawrence, and Butler Counties, Pennsylvania

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
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Geology and Hydrology of the Mercer Quadrangle, Mercer, Lawrence, and Butler Counties Pennsylvania

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Prepared by the United States Geological Survey,
Ground Water Branch, in cooperation with the
Pennsylvania Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG

1963

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CONTENTS

Page

Abstract 1
Introduction 2
  Purpose and scope of this investigation 2
  Location of the area 2
  Statement of the problem 2
  Methods of this investigation 5
  Well-numbering system 8
  Acknowledgments 10
  Previous investigations 10
  Geography 11
Geology 12
  Stratigraphy 12
    Mississippian System 12
      Shenango Formation 13
      Hempfield Shale 14
      Burgoon Sandstone 15
    Mississippian-Pennsylvanian contact 16
    Pennsylvanian System 17
      Pottsville Group 17
        Sharon Formation 18
        Connoquenessing Formation 19
          Lower member 19
          Middle member 20
          Upper member 21
        Mercer Formation 23
        Homewood Formation 25
      Allegheny Group 28
        Clarion Formation 28
        Vanport Limestone 33
        Kittanning Formation 35
          Lower member 36
          Middle member 38
          Upper member 38
        Freeport Formation 39
          Lower member 40
          Upper member 40
    Quaternary System 41
      Pleistocene Series 41
  Petrography 45

CONTENTS—Continued

Page

- Structure 46
- Sedimentation 49

Ground-water hydrology 53
- Principles of occurrence 53
- Ground-water fluctuations 54
- Circulation of ground water in the Mercer quadrangle 55
- Hydraulics 61
  - Definitions and principles 61
  - Hydrology of aquifers 64
  - Water use 71

Geochemistry of the ground water 71
- Laboratory analyses 71
- Field analyses 83

Conclusions 87

References 89

Appendix—Tables 3 to 6 92

ILLUSTRATIONS

FIGURES

Page

FIGURE 1. Map showing the location of the Mercer and adjacent quadrangles in Pennsylvania 3
2. Electric log of well La-150 7
3. Electric and sample logs of well Bt-17 9
4. Map showing facies and thickness of the Homewood Formation in the Mercer quadrangle 26
5. Map showing thickness of the Brookville coal bed in the Mercer quadrangle 30
6. Map showing facies and thickness of the Clarion Formation in the Mercer quadrangle 31
7. Map showing thickness of the Vanport Limestone and location of channel sandstone of the lower member of the Kittanning Formation in the Mercer quadrangle 37
8. Map of a part of northwestern Pennsylvania, showing distribution of glacial Lake Watts and Lake Edmund in front of the Kent ice sheet (after Preston, 1950) 43
9. Map showing structure contours on the top of the Vanport Limestone in the Mercer quadrangle .. 47
10. Diagram showing orientation of 145 joints 48
11. Diagram showing the dip directions of crossbeds in the Connoquenessing, Homewood, Clarion, and Kittanning Formations 50
12. Graph showing fluctuations of the water level in well Mr-526, and the daily temperature and precipitation at the U. S. Weather Bureau Station at Slippery Rock, Pa., in 1957 57
13. Idealized pattern of ground-water flow in the Mercer quadrangle 58
14. Graph showing drawdown in well La-485 during pumping 63
15. Graph showing drawdown in well Mr-949 during pumping 67
16. Map showing location of wells in the Grove City-Cooper-Bessemer Co. well field in Grove City, Pa. 68
17. Graph showing chemical analyses of water 72
18. Graph showing chemical analyses of water 74

ILLUSTRATIONS

FIGURES—Continued

Page

19. Graph showing chemical analyses of water 75
20. Graph showing chemical analyses of water 77
21. Graph showing chemical analyses of water 78
22. Graph showing relation of field conductivity to dissolved solids 79
23. Graph showing relation of field hardness to calcium plus magnesium 85
24. Map showing areal variation in field conductivity measurements of ground water in the Mercer quadrangle 86

ILLUSTRATIONS

PLATES

(All Plates in box)

PLATE 1. Map showing glacial deposits and the location of bedrock exposures in the Mercer quadrangle.
2. Bedrock geologic map of the Mercer quadrangle, Pennsylvania.
3. Fence diagram showing lithologic variation in the Mercer quadrangle.
4. Map showing location of wells in the Mercer quadrangle.
5. Electric and gamma-ray logs of wells in the west-central part of the Mercer quadrangle.

TABLES

Page

TABLE 1. Results of pumping tests 65
2. Summary of reported yields of wells 66
3. Record of wells 93
4. Chemical analyses of ground water 128
5. Field analyses of ground water 132
6. Sample logs of wells 142

GEOLOGY AND HYDROLOGY OF THE MERCER QUADRANGLE, MERCER, LAWRENCE, AND BUTLER COUNTIES, PENNSYLVANIA

By Charles W. Poth

ABSTRACT

Many deep valleys are cut in the Mississippian and Pennsylvanian rocks of the Mercer quadrangle. The floors and sides of the valleys are covered with glacial deposits of the Kent ice sheet (early Cary age), which completely fill some of the valleys. The glacial materials are as much as 200 feet thick in places.

The rocks of Mississippian and Pennsylvanian age that are discussed in this report are either exposed at the surface or crop out at the bedrock surface beneath the glacial deposits. From oldest to youngest they are: the Shenango, Hempfield, and Burgoon Formations of Mississippian age; and the Sharon Formation, Connoquenessing Formation, Mercer Formation, Homewood Formation, Clarion Formation, Vanport Formation, Kittanning Formation, and Freeport Formation of Pennsylvanian age. These rocks consist chiefly of sandstone and shale, but the Clarion and Kittanning Formations contain commercial deposits of coal. Except for the Vanport Limestone, the only limestones in the Mercer quadrangle are the thin beds in the Mercer and Freeport Formations.

The sandstones are composed chiefly of medium-grained quartz and contain a stable suite of heavy minerals. The most abundant heavy minerals are leucoxene, zircon, and tourmaline. The shales range from clayey to sandy.

Sharp lateral changes in lithology are common in these rocks. However, sandstone is most abundant along the western edge of the quadrangle, and shale predominates in the eastern part of the quadrangle, adjacent to the Butler County line.

The sediments were derived from the southeast and were deposited in a deltaic environment.

The mature dissection of the surface of the quadrangle forms "hydrologic islands" where precipitation enters the upper part of the "island" and is discharged from each of the aquifers into the glacial deposits in the valleys around the margin of the "island."

Both pores and fractures are avenues of movement of the ground water. Cement (chiefly silica) is irregularly distributed, so that the movement of the water may be restricted to a few zones that are less well cemented.

Pumping tests on 37 wells showed that the aquifers have a wide range in transmissibility. The transmissibilities ranged from about 100 to 400,000 gpd (gallons per day) per foot and were highest in the Burgoon Formation.

Yields of more than 1,000 gpm (gallons per minute) are obtained from wells tapping the Burgoon Formation at Grove City. Data on the Burgoon were available only at Grove City.

Yields of 200 and 300 gpm are reported from wells tapping the Clarion and Connoquenessing Formations.

Chemical analyses show that the ground water is of the calcium bicarbonate type, except where oxidation of iron sulfides associated with coal beds has produced large amounts of sulfate. Iron and sulfate are the most troublesome contaminants in the ground water of the Mercer quadrangle. A few wells yield water containing amounts of chloride larger than the average for the area, which is derived from the deep aquifers either by their discharge of water into the glacial materials in the deep valleys or from their discharge into aquifers through abandoned oil and gas wells.

INTRODUCTION

PURPOSE AND SCOPE OF THIS INVESTIGATION

The Lower Pennsylvanian and Upper Mississippian rocks in northwestern Pennsylvania constitute probably the largest undeveloped source of ground water in the Commonwealth. An understanding of the occurrence, availability, and chemical quality of the water in these rocks would contribute much to the orderly development of ground-water supplies for the large-scale industrial activities just beginning in this area. Accordingly, an investigation was begun in 1956 by the U. S. Geological Survey, in cooperation with the Pennsylvania Geological Survey. This report describes the results of that investigation in the Mercer 15-minute quadrangle.

LOCATION OF THE AREA

The Mercer 15-minute quadrangle is in western Pennsylvania between lat 41°00″ and 41°15′ north and long 80°00′ and 80°15′ west. (See Fig. 1.) The quadrangle includes parts of Mercer, Lawrence, and Butler Counties.

STATEMENT OF THE PROBLEM

Hydrologic features.—Some wells in the area yield more than 1,000 gpm (gallons per minute). Other wells, a few miles away, penetrate the same stratigraphic interval but yield less than 100 gpm. These differences in yields are the result of variations in lithologic and structural factors.

Sandstone may grade laterally into shale within a relatively short distance, or the vertical succession of strata may change. Thus, as these variations affect the yields of wells, it is important to know their location and nature.

The diagenesis of the sediments may be fully as important hydrologically as their depositional history. Buried sediments undergo compaction and cementation that decrease their permeability, and any differences in the degree of cementation between parts of the same formation or between different formations could produce major differences in the hydrologic properties of the rocks.

Structural deformation of the rocks may have a twofold influence on the hydrology. First, local uplift may raise part of a formation above that in adjacent areas and expose it to weathering and to local recharge. If the uplift occurs during deposition of the sediments, it could produce diastems or local thickening of the formation as well as the more common facies variations. Second, the uplift causes fracturing of the rocks. An area of well-indurated rocks may have relatively low primary permeability and, consequently, furnish only relatively small supplies of water

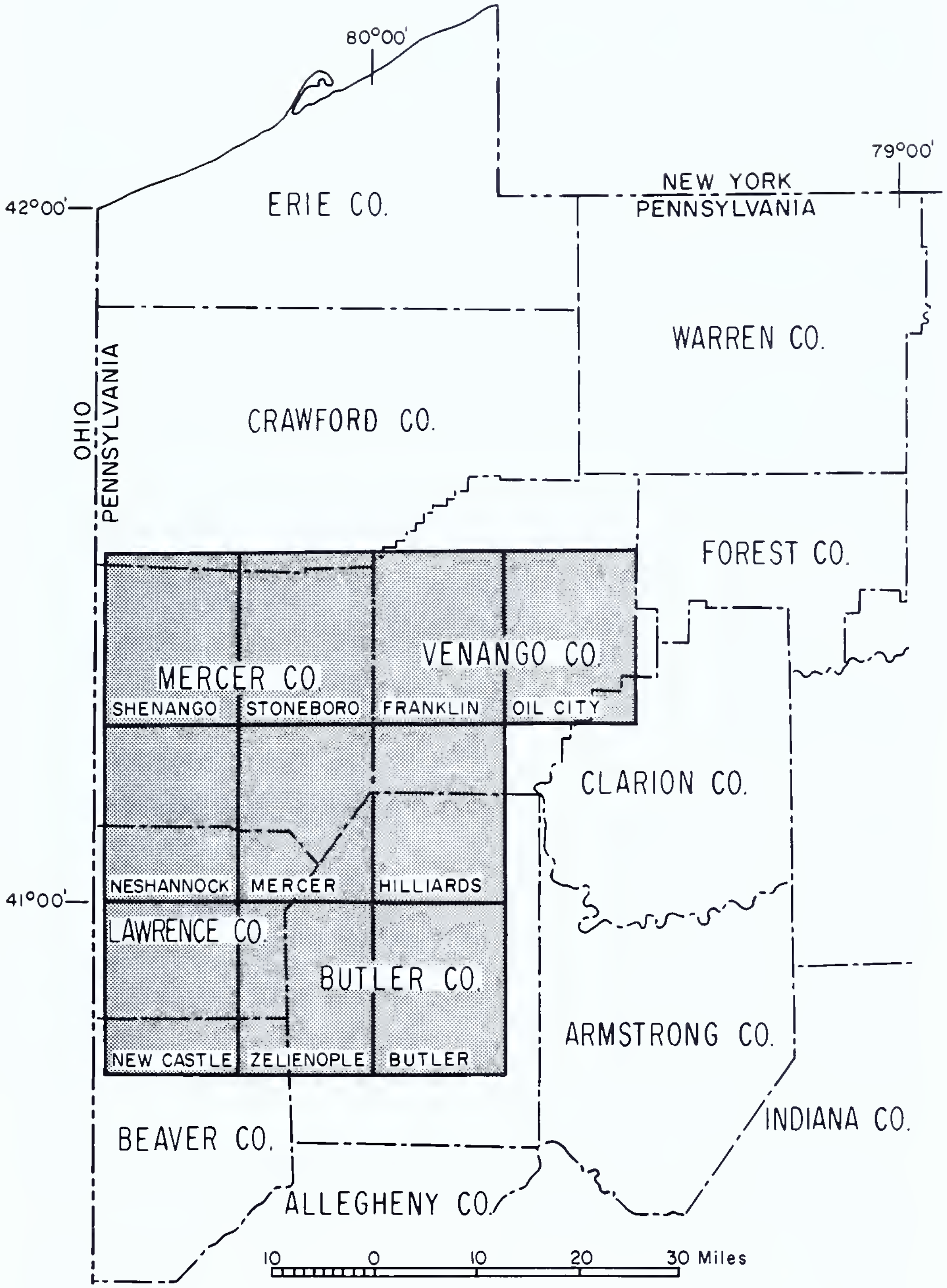


Figure 1. Map showing the location of the Mercer and adjacent quadrangles in northwestern Pennsylvania.

to wells, but fracturing of the rocks will increase their permeability. Furthermore, an irregular distribution of the fractures is probably the reason for the irregular distribution of large ground-water yields observed in the Mercer quadrangle.

Faulting, considered as a special case of fracturing in which movement takes place along the break in the rock, may be either helpful or detrimental to the ground-water supplies in the area. Like fracturing, faulting may increase the permeability of consolidated rocks, but the movement involved in faulting may place an aquifer opposite a less permeable rock body and, thus, inhibit the freedom of movement of the water through the aquifer and decrease the effective areal extent of the aquifer.

Geochemical features.—The chemical quality of the water in an area is just as important to the consumer as the quantity of water available. The chief water-quality problem in the Mercer quadrangle is the occurrence of low pH and high iron and sulphate in the water in certain parts of the area. The delineation of the area containing water having low pH and high iron and sulphate content, and the determination of what causes this type of water serve to focus attention on the geology, because knowledge of the geologic factors discussed in the previous section should indicate the cause and place of origin of the water and show the probable courses of movement of ground water in the affected areas.

Geological features.—The scarcity of fossils (especially in the sandstones) and the small utility of the fossils that are found make it necessary to map the geology on the bases of lithology and stratigraphic succession. However, marked changes in facies and in thickness of the formations within short distances make the tracing of formational contacts difficult. The multiple recurrence of similar depositional environments in the area during Mississippian and Pennsylvanian time resulted in the deposition of several similar sequences of rocks. In any study of these rocks great care must be used to avoid miscorrelations. These problems are further complicated by the scarcity of bedrock exposures, as glacial deposits blanket all of the Mercer quadrangle except the southeast corner. (See Plate 1.) In most of the Mercer quadrangle, the exposures of bedrock are limited to a few stream valleys, road cuts, old quarries, and coal strip mines. (See Plate 1.) They seldom exceed a few feet in thickness and rarely include a formational contact.

Operational features.—Because exposures were scarce, it was necessary to depend greatly on subsurface data from wells. Most of the data came from the drillers and owners of wells. Samples of the rocks penetrated by these wells generally were not available.

Most drilling activity in the area is concerned with the production of domestic water supplies; consequently, where adequate water supplies are obtained at shallow depth, information is rarely available on the lithology and yields of the deeper aquifers.

Some wells may penetrate several aquifers. For such wells it is desirable to determine the contribution of each aquifer if optimum use is to be made of the well.

Accurate determination of the hydraulic properties of the rocks presents some difficult problems. Laboratory methods would not be appropriate for this investigation because of the large number of samples that would be required to determine adequately the variability of the rocks. Furthermore, these samples are not available from either wells or fresh outcrops. Field methods for determining the hydraulic properties require a well that can be pumped while water-level measurements are made in one or more nearby wells in which the water levels fluctuate in response to the pumping. Many pumping tests in each aquifer would be required to evaluate that aquifer throughout the quadrangle. Because of the scarcity of satisfactory sites, only one pumping test was made during this investigation.

METHODS OF THIS INVESTIGATION

Geologic map.—Published geologic maps of the Mercer quadrangle show only the Allegheny and Pottsville Groups; so, it was necessary to remap the quadrangle in greater detail to gain a better understanding of the complex geological relationships in the area. (See Plate 2.)

Bedrock-contour map.—Early in the mapping program it became evident that the glacial deposits presented a problem beyond that of obscuring the bedrock. These deposits are several tens of feet thick over most of the quadrangle and are about 200 feet thick locally, in buried valleys. (See Plates 1 and 3.) To have ignored these Pleistocene deposits by extrapolating the bedrock geologic contacts to the land surface, would have presented an erroneous picture of the geology and would have hampered insight into some of the features that might control the occurrence of ground water. Therefore, a contour map was prepared that showed the configuration of the bedrock surface beneath the glacial sediments. The geologic map was then constructed on this surface.

The bedrock elevations used for preparing the contour map were determined from exposures in road and stream cuts, coal strip mines, and quarries, and from data obtained from test holes and the canvass of water wells.

Well data.—The best data obtained from the well inventory were those obtained from recently drilled wells for which the driller had kept careful logs. Wells for which only the depth of the casing and of the well were known were useful for depth-to-bedrock information, because the bottom of the casing is seldom driven more than 5 feet into the rock. The wells that were cased to the bottom were useful in a negative sense only, because they usually ended in glacial material and indicated only that the depth to bedrock was greater than the depth of the well. Most of these wells were in areas of thick sand and gravel; many of them exceeded 100 feet in depth and provided the only estimates available of the depth to bedrock in such areas. The information obtained from the canvass of water wells was supplemented by drillers' logs of coal test holes and oil and gas wells. Samples of drill cuttings were obtained from only a few wells.

Geophysical logging.—Electrical and gamma-ray logging are methods of measuring certain electrical and radioactive properties of the rocks penetrated by a well. As an electrode is lowered into the well, measurements of these properties are recorded on graph paper at the surface as a function of the depth of the electrode. During this investigation, point resistance, spontaneous potential, fluid conductivity, and gamma-radiation logs were made on 40 wells. In addition, a caliper log of the borehole diameter was made on some of the wells.

Many of the wells were abandoned oil or gas wells several hundred feet deep for which no other data were available, and the electrical and gamma-ray logs supplied valuable information on the lithology and thickness of the formations at these locations. These logs also were the only source of information on some of the deep beds that do not crop out in the Mercer quadrangle.

Where logs were obtained on several wells in a small area, they provided an insight into the facies changes that occur within small distances in Pennsylvanian and Mississippian rocks. Such an area was found about 1 mile southwest of Drake, Pa., in northeastern Lawrence County; it is discussed in the section on the Connoquenessing Formation.

A point-resistance log is a record of the variation in the resistance of the rocks in a water-filled borehole, opposite a moving electrode, to the passage of an electrical current. A gamma-ray log, on the other hand, shows the variation of the natural gamma radiation in the rocks.

The electrical resistance and gamma radiation of a rock have been shown to bear a close relationship to the lithologic properties of the rock. Relatively high resistance and low gamma radiation are associated ordinarily with sandstone, limestone, and coal; and low resistance and high gamma radiation are usually characteristic of shale. The presence in a sandstone of more than the normal amount of radioactive minerals, or the presence of a considerable amount of electrolytes in the interstitial water, may give the sandstone the characteristics of a shale on these logs. Unlike the point resistance, the gamma-ray log may be used in a dry hole or in the part of the well containing steel casing.

A spontaneous-potential log is a record of the difference in electrical potential between the earth at the surface and the rock opposite the electrode in the water-filled borehole. Under conditions usually met in oil wells, where the formation water is highly conductive (owing to dissolved sodium chloride) and the borehole fluid is relatively fresh, spontaneous-potential logs closely resemble gamma-ray logs. In most fresh-water wells, however, there is little difference between the conductivity of the formation water and the borehole fluids, and the electrolyte content of the waters is small; therefore, the spontaneous-potential logs frequently cannot be used for interpretations of lithology. The changes in spontaneous potential with depth are small and often erratic, so that the log may even appear as a straight or gently wavy line uninfluenced by changes in lithology. (See Fig. 2.) In this study the spontaneous-potential log has proved useful occasionally, in conjunction with point resistance

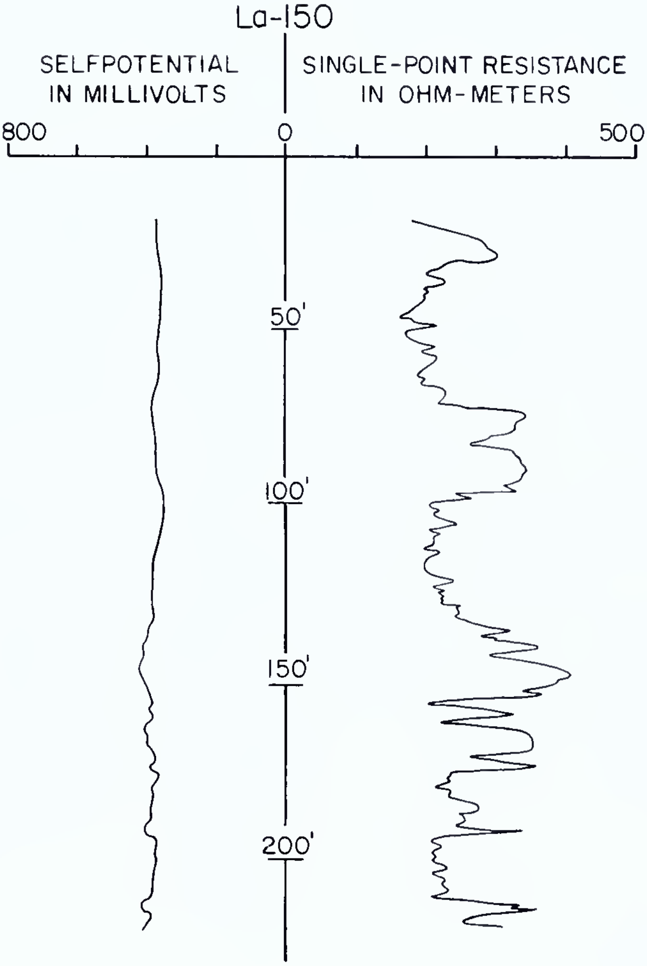


Figure 2. Electric log of well La-150.

logs, in delineating coal; this use is possible only when the coal is associated with concentrations of sulfides that have been at least partly oxidized, so that some highly conductive sulfuric acid is present. Examples illustrating the use of spontaneous-potential logs to locate coal beds are shown in Figure 3. The possibility of misinterpretation is still present, however, and the technique must be used cautiously and in conjunction with other evidence.

Many wells penetrate more than one aquifer, so that water moves out of the aquifer having the higher hydraulic head and into the aquifer having the lower head. If a slug of brine is introduced into the well, its direction and rate of movement in the well may be traced by means of a fluid-conductivity electrode, which measures the electrical conductivity of the borehole (Patten and Bennett, 1962). If the diameter of the well (shown by caliper log) is used in conjunction with the conductivity measurements, the volume of internal discharge may be estimated. This technique was useful several times during the investigation for estimating the volume of internal discharge and for determining which zones in the well were yielding or were capable of yielding water.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report includes an identification number and a location number. The well-identification number consists of a two-letter symbol for the name of the county followed by a serial number beginning with 1 in each county. The county symbols used in this report are Bt for Butler County, La for Lawrence County, and Mr for Mercer County. For example, Mr-60 identifies the 60th well scheduled in Mercer County.

The well-location number is composed of two parts separated by a hyphen—E3a-2612. The first part, "E3a", refers to the coordinate system used to identify the individual 7½ minute quadrangle maps. This system employs the use of the letter A through L (except I) along the west border of the State of Pennsylvania to designate from north to south each 15-minute interval of latitude. Similarly, the numbers 1 through 25 are used along the north border to designate from west to east each 15-minute interval of longitude. Each pair of coördinates designates a 15-minute quadrangle that is subdivided into four parts by using the letters a, b, c, and d to represent the northwest, northeast, southwest, and southeast quarters, respectively.

The second part of the well-location number consists of a four-digit number that identifies the northwest corner of a one-hundredth square-mile area within any 7½ minute quadrangle map. The first two figures refer to the number of tenths of a mile between the northern boundary

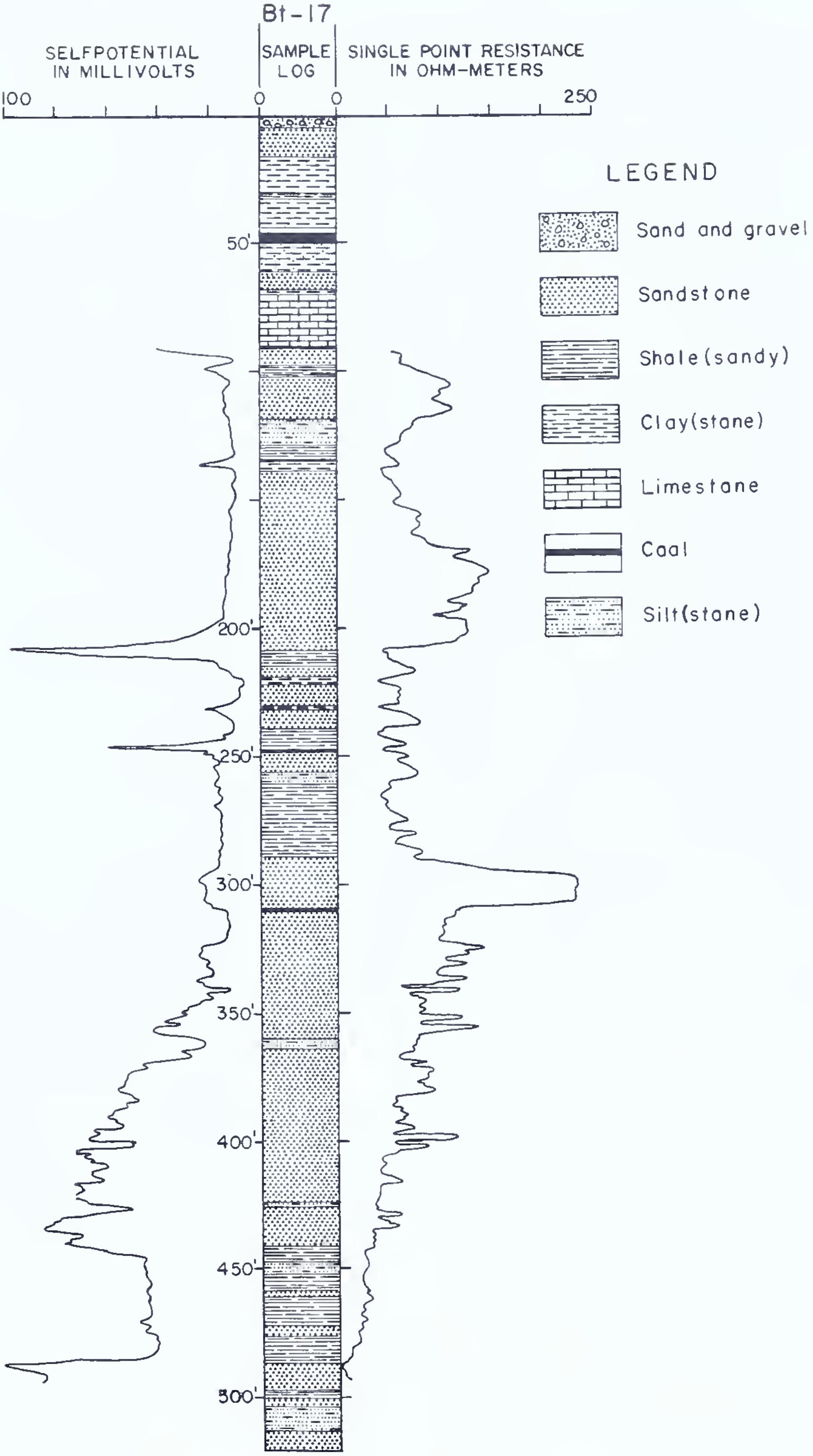


Figure 3. Electric and sample logs of well Bt-17.

of the 7½ minute quadrangle map and the northern boundary of the one-hundredth square-mile area containing the well site. The last two figures refer to the distance between the western boundary of the 7½ minute quadrangle map and the western boundary of the one-hundredth square-mile area containing the well site. Thus, a well having the location number E3a-2612 is situated between 2.6 and 2.7 miles south and between 1.2 and 1.3 miles east of the north and west boundaries, respectively, of the 7½ minute quadrangle designated "E3a".

The location of the wells is shown in Plate 4.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the drillers, industrial concerns, boroughs, and many local residents who have supplied information or allowed the use of their wells for hydrologic measurements. Special thanks are due to Messrs. U. S. Dean, Floyd Offutt, and Virgil Palmer, well drillers. The following coal companies were especially helpful: Bobo Coal Company, Bowie Coal Company, Ohio-Buckeye Coal Company, and E. N. Turner and Sons. The assistance given by Mr. Paul S. Tremel, of The Manufacturers Light and Heat Company; Mr. Richard Campbell, Plant Engineer of the Cooper-Bessemer Company; and Mr. Breckenridge, Borough Engineer of Grove City, is greatly appreciated.

Acknowledgment is made also of the services of the following U. S. Geological Survey personnel who worked on the investigation: Mr. T. E. Hendrix, a summer employee, spent part of the field seasons of 1954 and 1955 studying the geology in the Mercer and adjacent quadrangles; Mr. R. A. McCullough canvassed wells and made electric logs during the summer of 1955; and Mr. W. C. Roth canvassed wells, made electric and gamma-ray logs, and assisted with pumping tests during the period 1957 to 1960.

PREVIOUS INVESTIGATIONS

Reconnaissances of the geology of western Pennsylvania were made by geologists of the Pennsylvania Second Geological Survey and published as county reports (Chance, 1879; White, 1879, 1880). No subsequent geologic studies have been made of the Pennsylvanian and Mississippian rocks in the Mercer quadrangle, but reports on the geology of the following adjacent quadrangles have been published: the New Castle quadrangle (DeWolf 1929), the Butler and Zelienople quadrangles (Richardson 1936), the Hilliards quadrangle (Sherrill and Matteson 1939), and the Franklin quadrangle (Sherrill and Matteson 1941). (See Fig. 1.)

The glacial deposits of northwestern Pennsylvania are discussed briefly in the reports of the Pennsylvania Second Geological Survey and in more detail in the works of Chamberlin (1883) and Leverett (1902, 1934). DeWolf (1929) described the Pleistocene geology of the New Castle quadrangle.

Reports concerned more directly with the glacial geology of the Mercer quadrangle include Preston's (1950) discussion of glacial lakes along this part of the ice front and Sitler's (1957) detailed description and map of the glacial sediments of the Mercer quadrangle and adjoining quadrangles. An excellent summary of the present status of knowledge of the glacial geology of northwestern Pennsylvania is given by Shepps and others (1959).

The ground-water resources of western Pennsylvania were described by Leggette (1936) and Piper (1933).

GEOGRAPHY

Physiography.—The Mercer quadrangle is in the western part of the Allegheny Plateau Province (Fenneman, 1938, p. 283). All but the extreme southeast corner of the area lies within the Glaciated Allegheny Plateau. (See Plate 1.)

Glaciation produced many changes in the topography and drainage of the quadrangle. Preglacial valleys were filled by the glacial debris so that the surface relief is now less than that of the unglaciated Allegheny Plateau lying to the south and east. The elevation of the land is greatest along the eastern margin of the quadrangle, reaching a maximum of about 1,500 feet in Worth Township, Mercer County, in the northeast corner of the area. The surface of the land declines generally westward and reaches its lowest point at the western edge of the area, along Neshannock Creek, near the Mercer-Lawrence County line, where the elevation is about 1,000 feet.

The drainage system disrupted by the Wisconsin glaciation has not yet been completely re-established, as shown by the many swamps scattered throughout the area. Neshannock Creek and its tributaries are developing a drainage system in the northwestern part of the area, while the Wolf Creek-Slippery Rock Creek system is developing in the eastern and southern part. Both stream systems flow southwestward into the Beaver River, which flows into the Ohio River.

Climate.—Climatological data were taken from records of the U. S. Weather Bureau station at Grove City, which was established in 1907 and discontinued in 1942. Some of these data are shown in the following table.

Mean monthly temperature and precipitation at Grove City, Pa. for the years 1907-1942, inclusive.

Temperature (°F)		*Precipitation (inches)*	
Jan.	27.4	Jan.	3.14
Feb.	27.8	Feb.	2.30
Mar.	37.2	Mar.	3.14
Apr.	47.9	Apr.	3.26
May	58.3	May	3.92
Jun.	66.4	Jun.	3.98
Jul.	70.6	Jul.	4.18
Aug.	68.7	Aug.	3.32
Sept.	63.4	Sept.	3.36
Oct.	52.2	Oct.	3.20
Nov.	40.5	Nov.	2.92
Dec.	30.3	Dec.	2.91

The mean annual precipitation for the 36-year period of record was 39.63 inches. Mean monthly precipitation ranges from a low for February of 2.30 inches to a high for July of 4.18 inches.

The mean annual temperature for the period of record was 49.2°F. Mean monthly temperatures were lowest in January (27.4°F) and highest in July (70.6°F). The growing season averaged 138 days and the frost-free period extended from May 18 to October 3.

Population.—The population of the Mercer quadrangle, based on the preliminary report of the 1960 census, is estimated to be 28,000. About 48 percent of the people live in rural areas and the remainder in the following communities: Grove City (pop. 8,342), Mercer (pop. 2,800), Slippery Rock (pop. 2,581), and Harrisville (pop. 895).

GEOLOGY

STRATIGRAPHY

Mississippian System

A twofold subdivision of Mississippian rocks is generally recognized in Pennsylvania. The boundary between them occurs approximately at the boundary between the Chester and Meramec Series (Weller and others, 1948, p. 101).

In western Pennsylvania the lower unit has been divided into several formations or groups, from oldest to youngest they are: Cussewago Sandstone, Bedford Shale, Berea and Corry Sandstones, Cuyahoga Group (Orangeville Shale, Sharpsville Sandstone, and Meadville Shale), Shenango, Hempfield, and Burgoon Formations. They are characterized by white, gray, greenish or yellowish color and, with the exception of the Cussewago Sandstone and the Burgoon Sandstone, are probably marine in origin. They have been named from type areas in western

Pennsylvania or Ohio. Because some doubt still exists as to their exact correlation with the Pocono Formation of eastern Pennsylvania (Carlyle Gray, 1960, personal communication), the use of Pocono as a group [or series] term for these formations is avoided in this report.

The upper unit of Mississippian rocks is termed the Mauch Chunk Formation. It is characteristically red and is considered to be of continental origin. The Mauch Chunk is reported to be absent throughout the greater part of northwestern Pennsylvania, although red beds near the top of the Mississippian section in this part of the state have been noted occasionally by several geologists (Sherrill and Matteson, 1941, p. 10) and (Dickey and others, 1943, p. 14). Where the Mauch Chunk is absent, the Burgoon is overlain directly by rocks of Pennsylvania age.

No Mississippian formations are exposed in the Mercer quadrangle. However, the Shenango, Hempfield, and Burgoon Formations are present beneath the glacial sediments in the valleys of Neshannock and Wolf Creeks (Plate 2). The discussion of Mississippian strata, therefore, will be limited to these three formations.

Shenango Formation

Correlation.—The Shenango Formation was first named the Shenango Sandstone by I. C. White (1880, p. 60) from its occurrence along the Shenango River in western Mercer County, Pa. White described it as a very persistent, massive, and very ferriferous sandstone, containing large quantities of iron-ore balls, fish remains, and shells. The distinctive character of the sandstone makes it an excellent marker bed. White was able to trace it in outcrops from its type occurrence, near Sharon, Pa., northward and eastward through Mercer and Crawford Counties to Warren and Venango Counties—even though the formation increases in thickness from 3 feet near Sharon to about 40 feet at Warren and becomes increasingly pebbly east of Meadville (White, 1881, p. 81).

More recently, Sherrill and Matteson (1939, p. 7-8; 1941, p. 12-13) and Dickey and others (1943, p. 15-18), working in the Hilliards, Franklin, and Oil City quadrangles (see Fig. 1), described a much thicker and more complex formation that occurs at about the same horizon as the sandstone described by White. The formation is of uniform character throughout the Franklin and Oil City quadrangles, consisting of three sandstone members separated by clayey to sandy shale. The thickness ranges from 65 to 95 feet in the Franklin and Hilliards quadrangles and increases eastward to about 160 feet in the northern part of the Oil City quadrangle.

Although the upper member has not been traced into Crawford County, Sherrill and Matteson (1941, p. 12) believe that it becomes more shaly northwestward and that it is correlative with the upper part of the

Hempfield Shale. Sherrill and Matteson (1941, p. 12) believe the middle member is correlative with the Shenango Formation in Crawford County. The lower member probably represents a sandy development of the Meadville Shale of the Cuyahoga Group (Sherrill and Matteson (1941, p. 13).

In the Hilliards quadrangle the Shenango Formation lacks the five-fold character of the Franklin and Oil City quadrangles. It consists of interbedded sandstone and shale, the shale beds ranging in thickness from less than 1 inch to about 6 feet.

Lithology of the formation in the Mercer quadrangle.—The Shenango Formation is shown as an easily recognized unit on electric and gamma-ray logs from the Mercer quadrangle; so, it is treated here as a single formation, even though (as indicated above) it may ultimately be correlated with parts of three formations. Its thickness increases gradually eastward from 90, 80, and 93 feet in wells Mr-67, Mr-1183, and Mr-944, respectively, to 100, 113, and 110 feet in wells Mr-526, Bt-158, and Bt-19. (See Plate 3.)

In the northwest corner of the quadrangle, at well Mr-944, the formation consists of alternating beds of sandstone and shale that range in thickness from 1 to 22 feet. In the central part of the quadrangle, the sand content of the middle of the formation is much greater than in the northwest corner, although the top and bottom still consist of thin beds of sandstone and shale. In wells Mr-526 and Bt-19, in the east-central and southern parts of the quadrangle, the sand content in the middle and lower parts of the formation is even greater than in the central part, and the upper part remains thin bedded sandstone and shale.

Sample logs are available for only a few wells (Mr-1185, Bt-158, Bt-17, and Bt-19) in the eastern part of the quadrangle. Except for a few beds of medium-grained sandstone near the top of the formation (in well Mr-1185) the Shenango is composed of very fine- to fine-grained greenish-gray sandstone and dark-gray silty shale. The sandstone is friable in the upper part of the formation, but it is a little more cohesive in the lower part. Small flecks of muscovite, biotite, and carbonized plant remains are present in some places.

Hempfield Shale

I. C. White (1880, p. 59)applied the name Shenango Shales to the beds of sandy shale and flaggy sandstones that overlie his Shenango Sandstone. Caster (1934, p. 141) suggested that the name be changed to Hempfield Shale for exposures of the formation in Hempfield Township, Mercer County, Pa. [in keeping with modern rules of stratigraphic nomenclature, which prohibit the duplication of geologic names for units of the same rank].

Throughout the Mercer quadrangle, the thickness of the Hempfield Shale ranges from 40 to 60 feet. At a few places the Hempfield cannot be distinguished from the overlying Burgoon Sandstone, and the thickness cannot be determined.

Samples are available from wells Bt-19, Bt-17, Bt-158, Mr-1184, and Mr-1185 in the eastern third of the area, where the formation ranges from a light-gray siltstone to a dark-greenish silty shale. A few beds of very fine -to fine-grained sandstone are present in the lower part of the formation. Mudstone is abundant in the upper part of the section penetrated by well Mr-1185.

Burgoon Sandstone

Charles Butts (1904, p. 5) first applied the name Burgoon to about 300 feet of coarse sandstone exposed along the track of the Pennsylvania Railroad on the Allegheny Front in Blair County. Exposures of the formation are poor in western Pennsylvania so that it is known chiefly from well cuttings. Sherrill and Matteson (1939) report its presence in the subsurface in the Hilliards quadrangle, and Butts (1908, p. 193) states that it is absent at New Castle.

In the Mercer quadrangle the Burgoon Sandstone is best developed in the southeast corner. Northward and westward from there the Burgoon is thinner and in most places contains more shale. (See Plate 3.) The thickness decreases northward from 100 feet at well Bt-19 to 56 feet at well Mr-379. At the latter well the Burgoon consists of an upper shaly member 10 feet thick and a lower sandy member 46 feet thick. Well Mr-930, 1.8 miles west of well Mr-379, penetrated 40 feet of shale and 18 feet of sandstone of the Burgoon. Between wells Mr-379 and Mr-1184 the basal sandy member disappears, and the shaly member becomes indistinguishable from the underlying Hempfield Shale.

Data on the deep formations are lacking in the southwestern part of the quadrangle. However, farther north, in Washington and Springfield Townships, the electric and gamma-ray logs of several abandoned oil wells provide sufficient control to show that the Burgoon consists of a northwest-trending sandstone 30-40 feet thick. This sandstone grades laterally into shale and sandy shale within a short distance. (See Plate 5.)

Well logs indicate that the Burgoon is probably absent in the northwest corner of the quadrangle.

The areal limits of the Burgoon cannot be outlined precisely by using information available in 1960. However, the formation is probably absent a few miles beyond the west edge of the quadrangle—inasmuch as the formation is absent from the northern third of the quadrangle, appears to be confined to narrow channels in the west-central part, and thins northwestward from 100 feet at well Bt-19 to about 45 feet at well La-428.

Samples are available from wells Bt-17, Bt-19, and Bt-158, in the eastern part of the area, where the formation consists mostly of fine- to medium-grained, light-gray to greenish-gray sandstone. The sandstone is present in the samples chiefly as small chips, though some beds are sufficiently friable to yield samples composed predominantly of loose grains. Some of the samples contain muscovite, siderite, and carbonized plant remains.

Mississippian-Pennsylvanian contact

The position of the contact between Mississippian and Pennsylvanian rocks in western Pennsylvania has been the subject of much speculation. Exposures are scarce and fossils are rarely found in these rocks, so that interpretations are usually based on lithologic correlation of well samples and on standard intervals from certain marker beds. DeWolf (1929, p. 57-61) summarized the problems of classification and correlation of these formations in western Pennsylvania. The classification adopted in this report places the contact between the top of the Burgoon Sandstone and the base of the Sharon Formation (or Connoquenessing Formation if the Sharon is absent).

In this report, identification of the Burgoon, Sharon and Connoquenessing Formations is based chiefly on selected electric and gamma-ray logs of wells several hundred feet deep. The most valuable logs for such purposes are those from wells where the formations consist of prominent beds of alternating sandstone and shale, rather than those in which several formations are fused into a continuous sequence of sandstone or shale. Identification is made by beginning with a formation that is easily recognizable on the log, or one that may be correlated with a known exposure; the other strata are then named from the known stratigraphic succession. Following identification of the formations on the more easily interpreted logs, correlation is made with the logs containing less definitive sequences of sandstone and shale.

When the above procedure is applied to the log of the Hockenberry Well No. 1 (Bt-158), it becomes evident that those strata lying between 252 and 393 feet below the surface, and assigned to the Mississippian by Fettke (1961, p. 39), are correlative with both the Connoquenessing and Burgoon Formations. On the basis of such comparison, then, the present writer places the top of the Mississippian penetrated by this well at 330 feet below the land surface.

The exact nature or configuration of the contact in the Mercer quadrangle is somewhat obscure, because the facies changes in the Burgoon Sandstone obscure all evidence of tilting or extensive erosion of the

Mississippian sediments prior to the deposition of the Pottsville sands. Butts (1908, pl. VIII), by means of a geologic cross section along the Allegheny River, showed the Mississippian and Devonian sediments as rising northward in a series of gentle steps and the Pennsylvanian formations overlying older beds in that direction. Caster (1934, Fig. 12) revised the section to show a continuous, but far more gentle, northward rise of the pre-Pennsylvanian strata.

In their report on the Hilliards quadrangle, Sherrill and Matteson (1939, p. 6) stated: "Because of this unconformity the distance from the 'key' Vanport Limestone to Mississippian and Devonian sands increases about 40 feet southward across this quadrangle and has resulted in much of the misnaming of sands in the well records." Such indirect estimates of the dip may lead to errors because of changes in the thickness of the intervening formations. For instance, the thickness of the Pottsville Group changes from 178 feet at well Bt-19 to 222 feet at well Bt-17, chiefly because of changes in the thickness of the Mercer Formation.

Pennsylvanian System

The term Pennsylvanian, as applied to stratigraphy, was first used by H. S. Williams (1891, p. 83) to designate certain strata that extended from the base of the Pottsville "formation" to the top of the Dunkard "formation" in the northern Appalachian region. The Dunkard Group has subsequently been assigned to the overlying Permian System.

A fourfold division of the Pennsylvanian rocks is recognized in the western part of the Commonwealth. In ascending order, they are the Pottsville, Allegheny, Conemaugh, and Monongahela Groups. Only the lower two groups are present in the Mercer quadrangle and, accordingly, discussion is limited to them.

Pottsville Group

The Pottsville Group is divided into four major divisions. From oldest to youngest they are the Sharon, Connoquenessing, Mercer, and Homewood Formations. These formations are characterized by a preponderance of sandstone throughout much of their extent. They may differ considerably in lithology from place to place, and may, locally, be very shaly. This makes differentiation of the individual sandstones difficult, for where they are well developed, each of the sandstones is composed almost entirely of well-rounded, medium to very coarse quartz grains. Coal may be developed in each of the formations. The thickness of the group in the Mercer quadrangle ranges from 178 to 267 feet and averages 236 feet.

Sharon Formation

The Sharon Formation was named by I. C. White (1880, p. 51-58) for exposures of coal, shale, sandstone, and conglomerate near the city of Sharon, Pa. According to a recent study by Fuller (1955) of exposures of the Sharon in Ohio, it consists dominantly of medium-grained quartz sandstone that grades laterally into a series of conglomerate beds and was probably deposited in a deltaic environment. The Sharon is present in Ohio in three areas of outcrop, two in the northern part of the state and one in the southern part. Fuller believes the type area to be continuous with the Sharon in the easternmost of the two northern areas in Ohio and postulates a northern source for these rocks. The sands and gravels of the southern belt he believes were derived from the southeast.

The Sharon Formation is underlain by the Hempfield Shale and overlain by the lower member of the Connoquenessing Formation. In the Mercer quadrangle the Sharon is probably limited to the northwest corner, where it is tentatively identified in the log of well Mr-944. (See Plate 3.) In this well it consists of 22 feet of sandstone overlain by 28 feet of shale. Well Mr-929, about 2¾ miles northeast of Mr-944, penetrated 56 feet of soft shale at approximately the stratigraphic position of the Sharon Formation. The log of an oil well (Mr-1183) about 3 miles southeast of Mr-944 shows 140 feet of sandstone between the Hempfield and Mercer Formations. As this is approximately the thickness of the Connoquenessing Formation in this part of the area, and the underlying Hempfield also is of normal thickness, it is inferred that the shale and the sandstone units identified as Sharon Formation in well Mr-944 do not extend southward to well Mr-1183.

Criteria are lacking for positive identification of the Sharon Formation in well Mr-944. Because the Sharon and Burgoon Formations are bounded by the same units if one or the other of the formations is missing, and because the Burgoon is not known to occur with the Sharon, the strata identified as the Sharon Formation in well Mr-944 could, conceivably, be the Burgoon Sandstone. Inasmuch as the Burgoon has a southeastern source and thins northward and westward across the quadrangle, it appears to have no genetic relation to the tentatively identified strata in well Mr-944, which have a northern source and a small areal extent in the Mercer quadrangle. The sandstone identified as part of the Sharon Formation in well Mr-944 and the sandstone of the Burgoon may have been laid down simultaneously from different directions. If this were true, the region between these two sandstones would probably contain sandy shale and shaly sandstones deposited by the vigorous current and tidal action that would be present within the strait between the areas in which the sandstones were being deposited. If deposition of the two sandstones was not simultaneous, and these units were deposited in open water at different times, they would grade into shale that would become finer as the distance from the source increased. As the intervening area contains fine shale, the strata under consideration in well Mr-944 are identified as the Sharon Formation until their relationship to the Sharon of the type area can be determined.

Connoquenessing Formation

I. C. White (1878, p. 66) first applied the name Connoquenessing Sandstone to a formation above the Sharon Shales typically exposed along the Beaver River and the Connoquenessing Creek. According to White, the formation was composed of three members as follows: "(a) upper member, a very massive, hard, white sandstone, 40 feet to 50 feet; (b) middle member, darkish sandy shales, generally containing iron ore at the top, and sometimes a thin coal below, 35 feet to 40 feet; and (c) lower member, a hard, massive, grayish-brown sandstone, 20 feet to 25 feet." White (1879, p. 65-66) used the name Quakertown for the coal and "Iron Shales" of the middle member exposed near Quakertown Station, Pa.

In this report, the Connoquenessing Formation is defined as consisting of a lower member, composed of sandstone; a middle member, composed predominantly of shale but including also a bed of coal and local thin sandstones; and an upper member, composed of sandstone. The name Quakertown is restricted to the bed of coal in the middle member.

Lower member

The lower member of the Connoquenessing Formation is composed of sandstone and is the oldest unit exposed in the Mercer quadrangle. It is exposed in the northwestern part of the area only, as at stations 1-3 in Plate 1 (station 1 appears on the fence diagram in Plate 3 as 1182). The member, as exposed at stations 1 and 2, consists of light-gray, well-cemented, fine- to medium-grained, thin- to thick-bedded sandstone. About 10 feet of the member is exposed at station 1 and about 6 feet is exposed above stream level at station 2. The lower contact is concealed at each station, but the contact with the overlying black shale of the middle member may be seen at station 2.

At station 3, about 20 feet of the upper member and 35 feet of the lower member are exposed along a small stream. A covered interval of about 10 feet may include the middle member, although a driller's log of a nearby well (Mr-936) indicates that the middle member is probably missing, and the upper member is resting on the lower member.

Measurements of poorly defined crossbedding in the lower member at station 3 show that the crossbeds dip 19° S.50°W. and 19° N.35°W.

Samples from wells Bt-17, Bt-19, Bt-158, and Mr-1184, in the eastern third of the quadrangle, show that the member is predominantly fine-grained sandstone. The cementation of the sandstone increases downward within the member. Shale and occasional siderite fragments are common throughout the member in the southeastern part of the quadrangle and in the basal part throughout the quadrangle, but they become less common northward in the quadrangle.

The thickness of the lower member in the area ranges from 30 to 78 feet and averages about 50 feet. The base usually is difficult to determine accurately, however, because it lies directly on another sandstone over much of the area. The lower member thickens and thins gradually from place to place without significant linear trend and does not appear to be a channel-type sandstone.

Middle member

The middle member is composed predominantly of shale but also contains coal and thin beds of sandstone. The member is exposed at stations 1 and 2 only, in the northwestern part of the quadrangle. (See Plate 1.) At station 1 the exposure of the member is limited to a bed of coal 2 feet thick overlain by gray shale 1 foot thick. At station 2, at Hope Mills, the entire member is exposed either in the east bank of the Neshannock Creek or in a small tributary that enters Neshannock Creek at this station. Here the member is overlain and underlain by sandstone of the upper and lower members and consists of the following units:

	Thickness (in feet)
Connoquenessing Formation, middle member	
Shale, black	17
Siderite, black	½
Sandstone, gray, fine-grained, crossbedding dips 18° S.88°E.	4
Coal[1]	1
Shale, silty, black	½
Shale, platy, black	½
Underclay	1
Shale, black	15
Siderite, black	½
Shale, black	8

[1] White (1880, p. 144) called this coal the Sharon coal, apparently on the basis of its distance below the Brookville coal.

Subsurface data reveal that the middle member differs widely in thickness and character in the Mercer quadrangle. At well Mr-1184, at the northern edge of the quadrangle, the member is 37 feet thick and consists of 6 feet of black shale and coal underlain by 31 feet of mudstone containing one thin siltstone and one very fine- to fine-grained sandstone. At Grove City it is 2 and 4 feet thick at wells Mr-379 and Mr-945, and 8 feet thick at well Mr-390. It is 27 feet thick at well Mr-1131, at the western edge of Grove City, and 40 feet thick at well Mr-930, about half a mile farther northwest. At well Mr-67, in the west-central part of the quadrangle, the middle member is 14 feet thick. In the southeast, at wells Bt-25 and Bt-17, the member is represented by only 1 foot of black shale or coal. At well Bt-19, near the southern edge of the map, the coal is absent, and the member is represented by only 10 feet of shale.

Some insight into the nature of the changes in thickness is given by three wells in western Springfield township. (See Fig. C, Plate 5.) For example, in a distance of about 600 feet, from well Mr-595 to well Mr-388, the middle member thins from 54 feet to 16 feet. Between wells Mr-595 and Mr-383, a distance of about 2,000 feet, the middle member thins from 54 feet to 24 feet.

Upper member

The upper member is composed of sandstone. Exposures of the upper member are more abundant than those of the lower 2 members. They occur at stations 1-4, in the northwestern part of the quadrangle; station 5, east of Millbrook; station 6, at Springfield Falls; and station 7, on Slippery Rock Creek east of Harlansburg, Pa. (See Plate 1.) The contact between the upper member and the overlying or underlying units is exposed at stations 1, 2, and 6 only. The top of the member may be inferred at station 4 also by the exposures of shale of the Mercer Formation in gullies in an abandoned road a few hundred yards away.

The most complete exposure of the upper member is at station 4, where 55 feet of gray to buff, fine- to medium-grained quartz sandstone are exposed in an old quarry. The grains are well rounded and well cemented. Some clay is present in the interstices of the rock, but it is most abundant in some of the thinner beds. The rock becomes finely speckled or even rust streaked upon weathering, owing to oxidation of iron-bearing minerals. The sandstone is thin- to thick-bedded. Cross-bedding is not prominent, but, where present, it dips 16° N. 50° W.

The rock exposed at station 5 differs somewhat from that in the northwest corner of the area. The bed cropping out along the road at the top of the hill at station 5 is composed of clear, well-rounded, medium-grained, tightly cemented quartz grains. The rock has a sugary appearance on a fresh surface. At the crest of the hill about 1 foot of the bed is exposed and beneath that there is a covered interval 10 feet thick. Below the covered interval, 40 feet of light-gray, fine-grained, thin-bedded clayey sandstone is exposed.

At station 6, the following section is exposed:

	Thickness (in feet)
Homewood Formation	
Sandstone, light-gray, weathering dark gray to brown; medium to coarse angular grains; loosely cemented; iron staining in bands; beds 2 feet thick; crossbedding prominent, dip 27° N.85°W. in upper set, 27° N.37°W. in middle set, and 23° N.85°W. in lower set; forms upper falls	35
Sandstone, similar to above but beds 2 to 6 inches thick; crossbedding 27° N.30°W. and 25° N.44°W. component of dip seen in plane of falls is 8° W; forms top part of lower falls	22
Mercer Formation	
Coal	0.2
Connoquenessing Formation, upper member	
Sandstone, light-gray, weathering dark gray to brown, medium, well-rounded grains; well cemented; horizontal planar beds; extends downward to base of falls	8
Sandstone, medium-grained becoming fine- to very fine-grained near base of outcrop; beds less than 1 to 2 inches thick; downstream from base to falls	36

The sandstone above the coal resembles the Homewood Formation in appearance and stratigraphic position. Its top is about 35 feet below the top of the Vanport Limestone, which is exposed in a small quarry about 1 mile to the southeast. The coal is considered to be one of the coal beds in the Mercer Formation.

The sandstone below the coal resembles the Connoquenessing Formation, but because it appeared to be too high stratigraphically, it was initially considered to be part of the channel deposit of the Homewood Formation. However, the electric log of a nearby oil well (Mr-383), shows a continuous sequence of sandstone from the top of the middle member of the Connoquenessing Formation upward to a shale break that occurs at the same elevation as the coal in the face of the falls, so that the upper member of the Connoquenessing is 100 feet thick. If the log of well Mr-383 is compared with the logs of some oil wells in northern Lawrence County (Fig. C, Plate 5), correlation of this sandstone with the upper member is strengthened.

White (1880, p. 87) considered that the section at station 6 showed the 3 members of the Connoquenessing.

Station 7, east of Harlansburg, is an isolated outcrop 20 feet thick. The standstone is thick bedded and is composed of coarse, well-rounded, well-cemented quartz grains stained buff to brown by iron compounds. Locally the iron-bearing materials may be concentrated into dark-reddish-brown bands one-eighth to one-quarter inch wide.

Samples of the upper member are available from wells Bt-17, Bt-19, Bt-158, and Mr-1184. (See Table 6.) They consist of light-gray quartz sandstone containing grains that range in size from very fine to coarse but are generally fine to medium. The fine grains are present in the samples as aggregates, but the medium and coarse grains are generally present as loose grains. The grain size is generally coarsest at the base of the member and becomes gradually finer upward. This relationship exists at well Bt-17, except that the very fine grains are present throughout the member. Dark-gray and black shale are present in some samples, and plant remains are reported in some of the samples from well Bt-17.

The thickness of the member in the Mercer quadrangle ranges from 10 to 100 feet and averages 40 feet. It is considerably thinner throughout most of the eastern part of the quadrangle, where the average thickness is 25 feet. The maximum thickness in the eastern part of the quadrangle is 52 feet thick—in well Mr-379, at Grove City.

The most persistent unit in the upper member is about 24 feet thick. This unit is easily recognized on electric logs from much of the area by its high electrical resistance, nearly constant thickness, and its high degree of homogeneity in relation to the adjacent units. It is present in the following wells at the depth indicated in feet below land surface: well Bt-17, 290-310 feet; well Bt-25, 286-301 feet; well Mr-1131, 102-122 feet; well La-428, 206-231 feet; and well Mr-383, 116-140 feet.

The presence of the persistent unit over a large area and, where recognizable, near the base of the member suggests that the member is not a channel or fluvial sand but was probably deposited in a marine environment.

Mercer Formation

The name Mercer was applied first by Rogers (1858, p. 476-477) to a limestone bed two feet thick near the base of his Tionesta Group. White (1879, p. XXXI, 54-63) substituted the term Mercer Group for Tionesta Group because of exposures of this unit near the town of Mercer, Pa. He renamed the Mercer limestone the lower Mercer limestone. At the same time he applied the name upper Mercer limestone to Rogers' Mahoning limestone.

White recognized the following units in his Mercer Group, in ascending order: lower Mercer iron shales, lower Mercer coal, lower Mercer limestone, upper Mercer iron shales, upper Mercer coal underclay, upper Mercer coal, upper Mercer limestone, Tionesta iron shales, and Tionesta coal. The lower, upper, and Tionesta units resemble one another so closely that it is difficult to identify them in isolated outcrops.

In this report the Mercer is termed a formation and consists of shale and interbedded sandstones, coals, and limestones. If the shale grades laterally into sandstone at the top of the formation, the sandstone is considered to belong to the Homewood Formation. If the shale grades laterally into sandstone at the bottom of the formation, the sandstone is assigned to the Connoquenessing Formation. Where identification is possible, the coals and limestones are named in accordance with White's terminology.

Few outcrops of the Mercer Formation are present in the area and those that are present consist generally of a few feet of nondescript gray silty shale. The single exception is at station 8, where the following section is exposed beneath the massive sandstone of the Homewood Formation:

	Thickness (in feet)
Mercer Formation	
Limestone, dark gray, silty; contains abundant brachiopods and crinoid stems	3
Shale, black, carbonaceous; contains abundant brachiopods and crinoid stems	2
Clay, dark gray	5
Shale, dark gray	8
Shale, dark gray, sandy	2

The Mercer is underlain at station 8 by the upper member of the Connoquenessing Formation, which is exposed in several places in the next 30 feet.

Samples of the Mercer Formation from wells Mr-1184, Bt-158, Bt-17, and Bt-19, show that the Mercer consists predominantly of dark-gray silty shale, containing carbonized plant fragments. Beds of fine-grained sandstone are present in all but the northernmost well; their thickness ranges from 4 to 11 feet, and averages about 7½ feet. In well Bt-17 these sandstone beds constitute about one-third of the formation.

The Mercer Formation contains two or three coals throughout most of the quadrangle. The thickness of the coals ranges from 2 to 60 inches but is generally 12 to 24 inches. The uppermost coal lies about 60 to 80 feet below the top of the Vanport Limestone and is tentatively correlated with White's (1879, p. XXXI, 54-63) Tionesta coal bed. It is about 30 to 40 feet above the next lower coal except in the east-central and southeastern sectors where the interval is 6 feet in wells Bt-160 and Bt-19. The interval between the middle coal bed and the lowest bed ranges from 7 to 45 feet and averages 25 feet. The middle and lower coals are probably correlative with White's upper and lower Mercer coal beds.

Limestone is present in one outcrop (station 8) and is reported in two wells (Bt-88 and Mr-1178). The limestone in the outcrop is tentatively identified as the lower limestone, and those in the two wells are identified as the upper limestone because of their stratigraphic position above the Connoquenessing Formation.

The thickness of the formation ranges from a featheredge to 100 feet and averages about 55 feet. The Mercer Formation is thickest in the eastern part of the area where the upper member of the Connoquenessing Formation is restricted to the persistent unit. (See section on Connoquenessing Formation.) Thinning of the Mercer takes place chiefly by interfingering with the upper member of the Connoquenessing, as shown in Plate 5, and also by erosion of its upper surface prior to the deposition of the Homewood Formation. These two causes combine, in the west-central part of the Mercer quadrangle, to reduce the thickness of the Mercer Formation to nearly zero.

Homewood Formation

The name Upper Homewood Sandstone was applied by White (1878, p. 67) to a massive sandstone exposed at Homewood Station in Beaver County, Pa. The use of the term Upper was abandoned in the succeeding report on Mercer County (White, 1880). White (1878, p. 67) stated that the sandstone reached its maximum thickness of 155 feet at Homewood Station and extended "* * * far up above its usual horizon, * * * cutting out the members of the Clarion Coal Group to above the Ferriferous Limestone * * * ." Study of this formation and overlying ones in the Mercer quadrangle suggests that the large thickness mentioned by White may be the result of deposition of sandstone in a channel of early Kittanning age that cut through the Ferriferous or Vanport Limestone and Clarion Formation into the Homewood, rather than the result of an upbuilding of the Homewood. The matter is discussed further in the section on the Kittanning Formation.

In this report the Homewood is called a formation. Throughout most of its extent the Homewood is a sandstone that grades upward locally into sandy shale or shale. (See Fig. 4, area A.) In the east-central part of the quadrangle, the Homewood becomes a complex of shale containing thin beds of sandstone and sometimes one or more beds of coal. (See Fig. 4, area B.) Logs of a few wells indicate that the sandstone is absent. Where the sandstone is absent, it is impossible to distinguish (in the available logs) the shale of the Homewood Formation from that of the underlying Mercer Formation. The shale is, therefore, classified as Mercer, and the Homewood is considered to be absent.

Outcrops of the Homewood Formation are numerous in the Mercer quadrangle, although they are generally only a few feet thick and include neither the top nor the bottom of the formation. Exposures of the top or bottom were noted or their positions could be estimated at stations 6, and 8-13 only. Estimation of the nearness of the exposure to the top or bottom of the formation, where the contact is not exposed, is sometimes possible from a second exposure a short distance away. For example, the Brookville coal bed (which overlies the Homewood) is exposed along the road 0.15 mile south of station 6, where it is 2 feet higher than the sandstone at station 6. From this relationship, the upper limit of the Homewood Formation at station 6 is established.

There are important outcrops of the Homewood at stations 14-20. These exposures are as much as 50 feet thick, but their positions with respect to the upper or lower boundary of the formation cannot be located precisely.

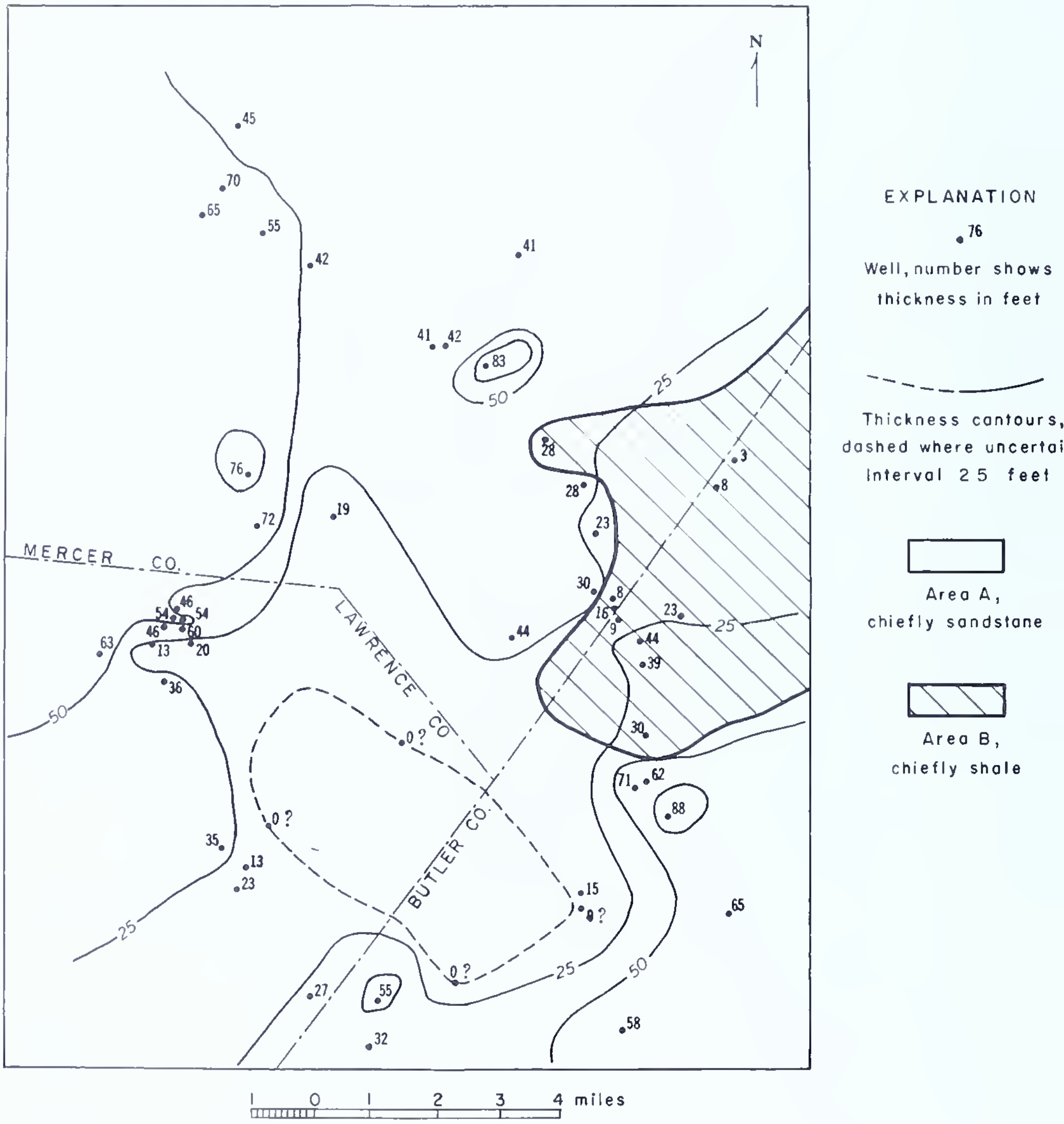


Figure 4. Map showing facies and thickness of the Homewood Formation in the Mercer quadrangle.

The upper part of the Homewood Formation, in area A of the Mercer quadrangle, is generally a tan, very fine- to fine-grained sandstone or shaly sandstone. The beds are generally 1 inch or less thick. Exposures at stations 8, 10, and 13 illustrate the nature of this upper phase of the formation. At station 13, which consists of an intermittent exposure in a ditch along Route 78, and in the bed of Slippery Rock Creek, at Dougherty Mills, the formation is fine grained and thin bedded throughout approximately four-fifths of its thickness. Only the basal 10 feet of the formation consists of well-sorted, medium-grained sandstone.

In most places where the thin-bedded or shaly phase is present, the Homewood grades downward through a thin transition zone into a medium- to very coarse-grained, thick-bedded sandstone nearly free of clay matrix. Crossbedding is generally prominent. The quartz grains are well rounded and fairly loosely cemented. On a fresh surface the Homewood is gray, but in outcrop it is commonly buff to brown, and at station 17 it is brick red. Casts of plant stems and roots may be abundant locally, as at stations 12, 13, and 15. Conglomerate zones are present near the base of the formation at stations 8 and 9; the pebbles are usually mudstone and may be as much as 2½ inches in length.

Subsurface data show that the Homewood Formation undergoes more rapid facies changes than is indicated in surface exposures. Well Bt-70, about 500 feet northeast of station 13, penetrated 43 feet of sandstone instead of the mere 10 feet exposed at station 13. Well Bt-100, 800 feet east of station 13, penetrated 65 feet of sandstone of the Homewood Formation.

The average thickness of the Homewood is about 50 feet in area A and may exceed 70 feet, as in wells Bt-17 and Mr-69. The formation is thinnest in the zone southwest of area B, where it is 20 feet thick in well La-172, 23 feet in well La-150, and 13 feet in well La-674. Although the Homewood is reported to be absent at 4 wells in this zone, other nearby wells or outcrops encountered sandstone beds of the Homewood ranging from 10 to 22 feet in thickness. Additional data might show that area B should be extended to include some of the area to the southwest.

The lithology of the Homewood Formation in area B is known only from wells. Several wells may be cited to show the variety of the lithology of the Homewood Formation in this area. A driller's log of well Mr-390 gives the following information on the lithology of the formation:

	Thickness (in feet)
Homewood Formation	
Sandstone, white	2
Shale and clay, dark-gray	17
Coal	½
Sandstone, dark-gray	9

In well Bt-158 the Homewood is 88 feet thick and consists of 4 feet of basal sandstone, 84 feet of shale, and several interbedded coals or carbonaceous zones. (See Table 6.) Plate 3 illustrates the lithologic changes that occur.

Allegheny Group

The Allegheny Group is divided into four formations. In order of decreasing age they are: Clarion Formation, Vanport Limestone, Kittanning Formation, and Freeport Formation. Shales and shaly sandstone make up the bulk of the group. The sand grains are typically fine to medium and generally subangular. Dark minerals such as biotite, hornblende, or coal fragments may be conspicuous.

Channel sandstones are common, but they are generally thin and rarely penetrate even the upper part of the underlying formation or member. A notable exception is the sandstone in the lower member of the Kittanning Formation. This sandstone occupies a channel that cuts through both the Vanport Limestone and the Clarion Formation. In such places the sandstone resembles the sandstones of the underlying Pottsville Group, and many times it has been mistakenly identified as such.

The Vanport Limestone serves as an excellent marker bed wherever it is present. Coals of commercial value are associated with each of the detrital formations. The thickness of the group in the Mercer quadrangle is about 300 feet (based on composite sections), but this does not include the upper part of the Freeport Formation, which is not present in the quadrangle.

Clarion Formation

The name Clarion is derived from Clarion, Pa., where the Clarion Formation was first studied by Rogers (1858, p. 476). Rogers used the name Clarion as a group term to include those rocks lying between the top of the Tionesta (Homewood) Sandstone and the base of the Freeport Sandstone. The part of the group overlying the Vanport Limestone was subsequently classified separately as the Kittanning coal group, and the Clarion Group was renamed the Clarion coal group (Lesley, 1877, p. XXIII). In the present report, the Clarion is ranked as a formation and restricted stratigraphically to exclude the Vanport Limestone.

The Clarion Formation is a complex lithologic unit composed of shale, sandstone, and at least two coals and their underclays. The base of the formation is defined as the base of the Brookville (or lower) coal or the base of its underclay, if the underclay is present. The Scrubgrass coal occurs near the top of the formation. In some places this upper coal caps the formation, but in other places it is overlain by a thin bed of shale, which is the uppermost unit of the formation.

The identification and correlation of the lower coal have been the subject of much speculation. It was identified in the Mercer quadrangle as the Brookville coal bed by White (1880, p. 28), and the name is in popular usage in the area at the present time; it is, therefore, retained in this report.

Geologists of the First Geological Survey of Pennsylvania failed to identify precisely which of the several coals present at Brookville, Pa., they considered to be the Brookville coal bed (Graeber and Foose, 1942, p. 50). Subsequent workers (Ashley, 1945, p. 375; Graeber and Foose, 1942, p. 51; and Williams, 1960, p. 914) have shown that the lowermost coal at Brookville is probably of Mercer age. The next two higher coals are correlative with the lower and upper Clarion coal beds at Clarion, Pa. Williams (1960, p. 914) showed that the Brookville coal of the Mercer quadrangle is probably correlative with the lower Clarion coal of the type section.

The Brookville coal has been mined extensively in the Mercer quadrangle. As a result, its character and thickness are fairly well known throughout the quadrangle. Figure 5 shows these variations in thickness. The coal is absent in the northwestern and extreme northeastern parts of the quadrangle, owing to erosion. In the southern part of the area, the coal thins and then grades into black shale. The Brookville reaches its greatest thickness in the central part of the area. Pyrite is present in the coal throughout most of the area where the coal is mined, but it is absent near the southern edge of the mined area.

A third coal is present in the Clarion Formation in some areas. It was called the Clarion coal by White (1879, p. 50) and was presumed correlative with the upper Clarion coal of the type section by Williams (1960, Fig. 3). White (1880, p. 27) reported that it crops out along the Hettenbaugh Run, in Lawrence County, 30 feet above the Brookville coal.

The Clarion coal is either absent in the Mercer quadrangle or is combined with the underlying Brookville. Logs from the following stations, though inconclusive, suggest that it may have combined with the Brookville. In a coal-test hole at Station 22, the Brookville is reported to be represented by two coal beds (one 4 feet thick and the other 3 feet thick) separated by 2 feet of clay. A coal-test hole, Station 24, penetrated 5 feet of soft black shale, 20 inches of coal, 10 inches of soft clay, and 39 inches of coal. At Station 25, near Albin School, another test-hole passed through 8 inches of "slaty" coal, 12 inches of clay, and 24 inches of coal.

Chance (1879, Fig. 3) illustrates a similar stratigraphic section in northeastern Butler County in which a shale separating two beds of coal thins from 15 feet to 1 foot in a distance of 3½ miles.

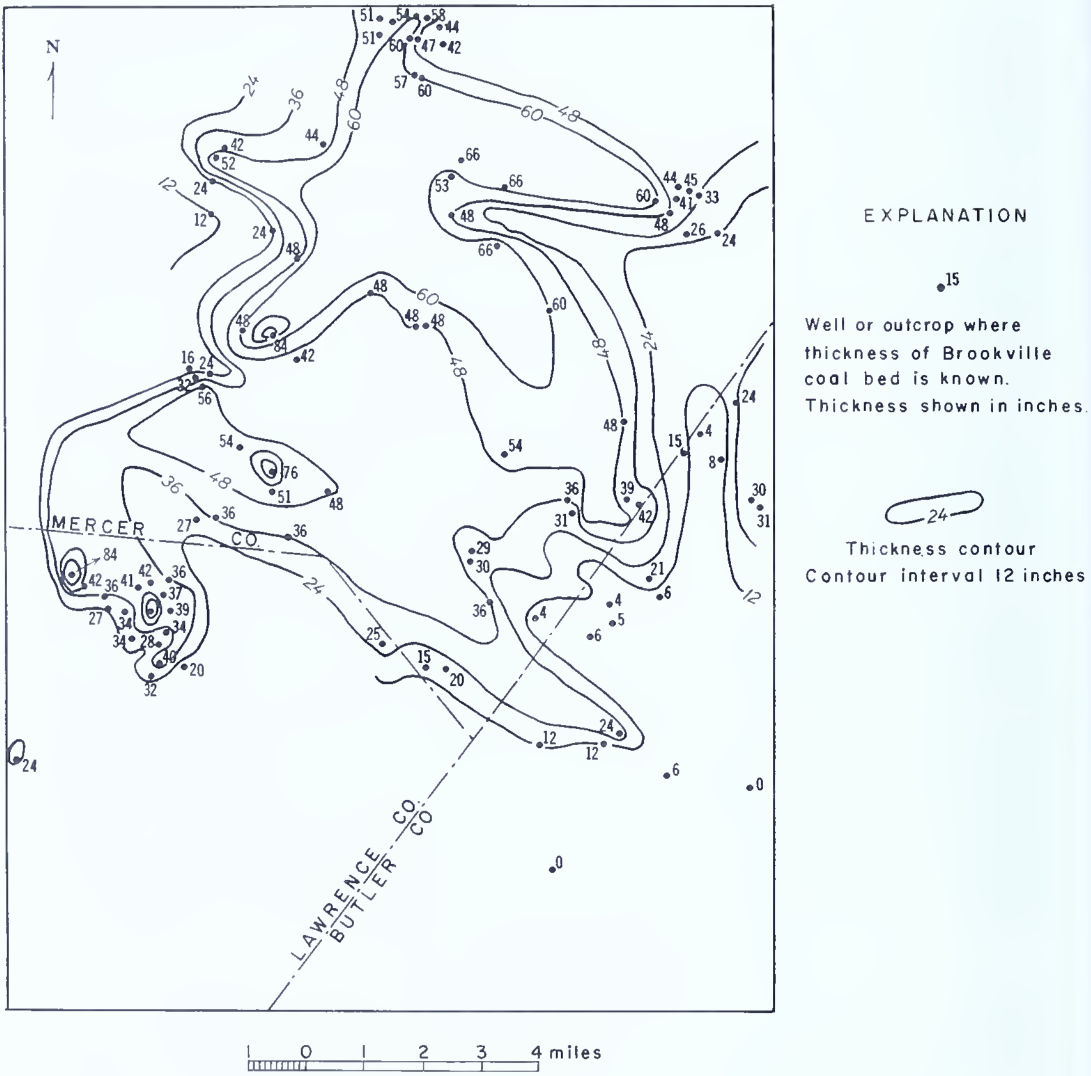

N
MERCER CO.
LAWRENCE CO.
BUTLER CO.
EXPLANATION
15
Well or outcrop where thickness of Brookville coal bed is known. Thickness shown in inches.
24
Thickness contour
Contour interval 12 inches
1 0 1 2 3 4 miles

Figure 5. Map showing thickness of the Brookville coal bed in the Mercer quadrangle.

Data concerning the underclay of the Brookville are scarce, but its thickness in the Mercer quadrangle, as reported in drillers' logs, ranges from 2 to 28 feet and averages about 20 feet.

The lithology of the section between the Brookville and the Scrubgrass coals is shown in Figure 6. Shale is the only rock present throughout most of the area, and sandstone is present in only narrow elongate zones in the southern and eastern parts of the quadrangle. The sandstone occurs as thin beds in the shale or as a major sandstone unit occupying most of the interval. Complete exposures of the Clarion Formation are so rare that most of the information concerning the formation has been obtained from wells.

Throughout most of its extent the shale of the Clarion is gray on a fresh surface, weathering to yellow, tan, or even red. It is usually thin-bedded and ranges from clayey to sandy. At station 26, just east of

Harlansburg, Pa., about 20 feet of silty shale is exposed beneath the underclay of the Scrubgrass coal. This is the largest exposure in the quadrangle of the shale phase of the formation.

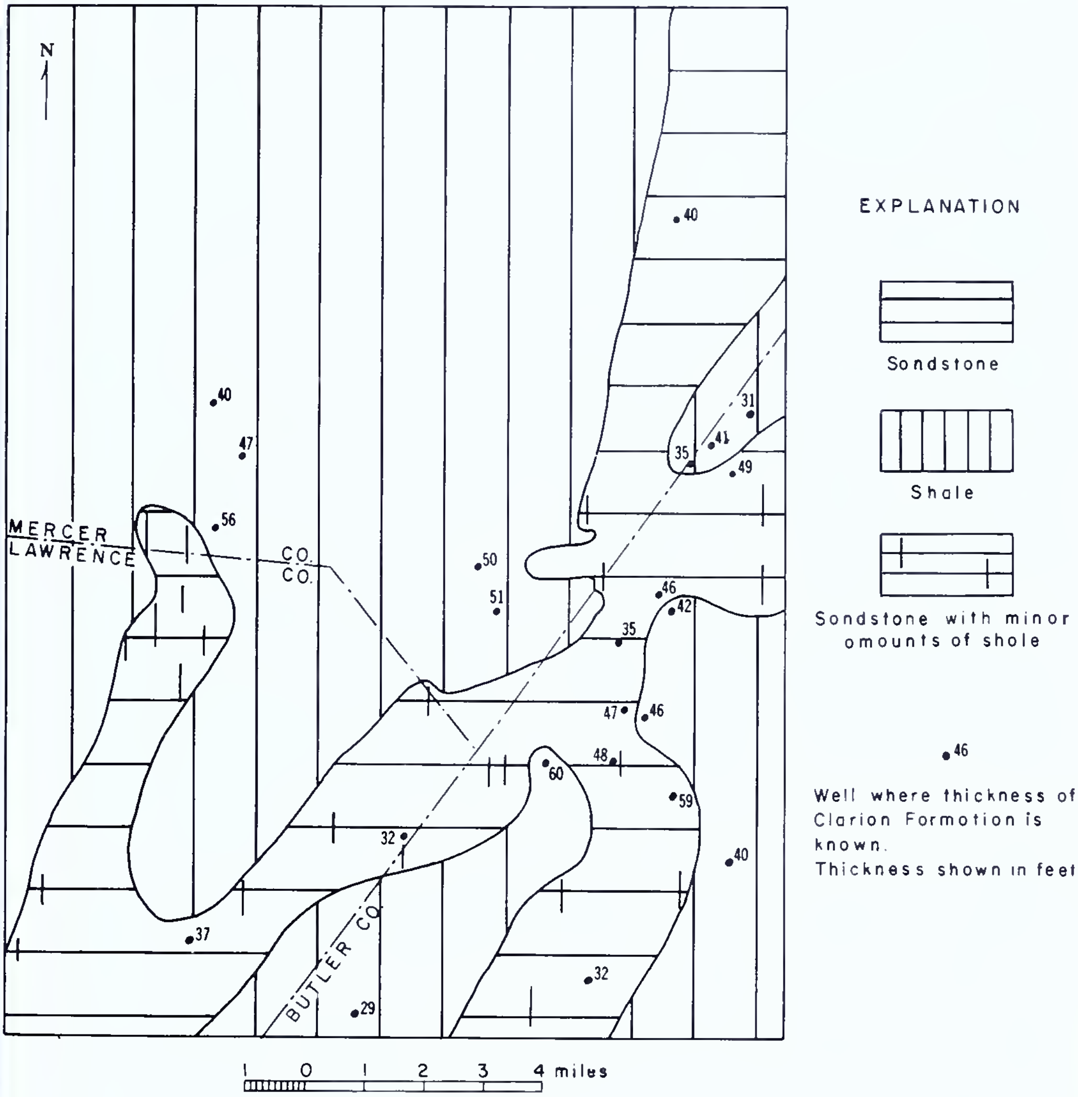


Figure 6. Map showing facies and thickness of the Clarion Formation in the Mercer quadrangle.

In the northwestern part of the quadrangle, the shale grades into mudstone, which ranges in color from gray to black. The mudstone is exposed in abandoned strip mines at stations 23, 28, and 29.

Exposures of the Clarion Formation consist chiefly of sandstone despite the restricted extent of the sandstone phase. Nearly all of the formation crops out along Slippery Rock Creek at station 30. The section exposed at station 30 is described below:

	Thickness (in feet)
Clarion Formation	
Coal, (Scrubgrass)	1¼
Underclay	¼
Shale, tan, silty	4
Sandstone, light gray, fine-grained; grains angular; abundant clay matrix; poor crossbedding dips 10° N.55°E.	20
Shale, reddish-black, clayey	6½
Shale, black, carbonaceous (Brookville)	½
Underclay	5

Farther north, at station 31, the following section is exposed in a strip mine:

	Thickness (in feet)
Clarion Formation	
Sandstone, tan, fine grained; grains angular; abundant clay matrix; crossbedding dips N. 30° W.	10
Sandstone, as above but planar bedded	10
Shale, tan, clayey; abundant plant fossils	10
Coal (Brookville)	2
Underclay	1

At station 32 the Clarion Formation is exposed in a large strip mine. Throughout most of the mine the sandstone is approximately 20 feet thick and lies directly above the Brookville coal. The sandstone is overlain by 7 to 10 feet of dark-gray shale containing numerous gnarly carbonaceous bands and 2 feet of "slaty" coal (Scrubgrass). Crossbedding in the sandstone dips S.80°W. At the west end of the strip-mine pit about 6 feet of gray to tan clayey shale is present between the base of the sandstone and the Brookville coal.

Subsurface data show that the sandstone may thin and disappear within short distances. For example, the sandstone is 15 feet thick in well Mr-1187, near Courtney Mills; it is absent from well Bt-161, about 800 feet to the south; and it is only 3 feet thick in well Mr-1186, about 800 feet north of well Mr-1187.

The Scrubgrass coal bed is a poor-grade coal of wide areal extent. In the Mercer quadrangle its thickness ranges from 2 to 36 inches and averages 16 inches. It is thinnest in the central part of the quadrangle, where it is reported to grade locally into black shale. Stations 29, 30, 32, and 34 furnish good exposures of the Scrubgrass. Underclay is generally present beneath the coal; its thickness ranges from 0 to 8½ feet and averages about 2 feet.

The thickness of the Clarion Formation in the Mercer quadrangle ranges from 29 to 74 feet and averages about 45 feet. The formation is thinnest in the vicinity of the Butler County line and reaches its maximum measured thickness at station 29, at the northern edge of the quadrangle.

Vanport Limestone

The formation overlying the Clarion was named the Ferriferous Limestone by geologists of the First Geological Survey of Pennsylvania (Rogers, 1858, p. 476). In his report on the Beaver River district, White (1878, p. 60) used the term Vanport Limestone synonymously with Ferriferous limestone, because of excellent exposures of the limestone near the town of Vanport, on the Ohio River, in Beaver County, Pa. In subsequent work in Lawrence and Mercer Counties, White (1879, 1880) returned to the older name. The geographical name has been formally adopted in modern reports (DeWolf, 1929, p. 44; Richardson, 1936, p. 19), however, and the limestone is now known as the Vanport. In this report it is ranked as a formation.

The name Ferriferous Limestone was derived from the local occurrence, at the top of the limestone, of a limonitic iron ore called the Buhrstone iron ore. According to White (1879, p. 40), the ore is generally 1 to 4 feet thick, but "* * * was found 22 feet thick at one locality, thus replacing the Ferriferous limestone entirely, since this is the thickness of the latter stratum in the vicinity."

The ore is exposed at station 34 at Harlansburg, Pa.

The Vanport Limestone is recognized easily throughout most of its extent, and it is the only good stratigraphic marker in most of the Mercer quadrangle. In most places where it is present in the quadrangle, the Vanport is a dense, light-gray limestone containing marine fossils. This typical phase is partially exposed in many places throughout the quadrangle, but it is completely exposed in only a few places, as at Station 34, in a road cut at Harlansburg, Pa.; at Station 36, on Slippery Rock Creek; at Station 35, in an abandoned limestone quarry near Heath, Pa.; at Station 33, in an abandoned coal strip mine in Wolf Creek Township; and at Station 29, in a strip mine at the north-central edge of the quadrangle. Data on the surface exposures are supplemented by information from wells.

The formation thins rapidly northwestward and undergoes a sharp change in lithology. The following section is exposed in an abandoned strip mine southwest of Blacktown, Pa., at Station 23:

	Thickness (in feet)
Kent outwash	
Sand and gravel	25
Kittanning Formation, lower member	
Shale, dark-gray, clayey; numerous siderite nodules at different levels, occasionally joining to form beds one-half inch thick; nodules may be fossiliferous	12
Vanport Limestone	
Limestone, silty; composed of 2 beds of similar thickness; fossiliferous	1½
Clay, dark-gray, calcareous	1½
Limestone, bed of tubular nodules of irregular thickness, somewhat flattened; contains some brachipods	¼
Clarion Formation	
Shale, dark-gray, becoming blacker downward, calcareous; discontinuous calcareous nodules in beds at different levels	8
Shale, black, platy, becoming canneloid downward	5
Coal, cannel	½
Shale, black, silty	1
Coal, bituminous	3

The several beds of nodular limestone are all that remain of the Vanport Limestone.

Farther north, at Station 28, the Vanport is represented by a discontinuous bed of dark-gray sandy limestone 4 inches thick. This thin, sandy limestone is present also at the base of the more typical Vanport, in part of the exposure at Station 29.

The thickness of the Vanport, in the Mercer quadrangle, ranges from zero to a reported 50 feet at Stations 37 and 38, south of Plain Grove, Pa., and averages 17 feet. Figure 7 shows the areal variations in thickness within the quadrangle.

The range in thickness is due to a number of factors: for example, changes in the conditions in the depositional basin from place to place—such as depth and salinity of the water; the amount of oxygen and nutrients present; and the supply of clastics, which control the amount and nature of the marine life and, in turn, determine the thickness and character of the limestone in different parts of the basin. Changes in the relative importance of these factors from place to place produce a systematic change in the thickness and character of the limestone. Also, a number of post-depositional changes may occur, such as the formation of solution channels or the erosion of the formation and subsequent deposition of another formation in its place. In some places, solution may progress to the point where the roof of the channel collapses, and the formation becomes much thinner. In other places, the roof may be strong enough to avoid collapse, and the solution channel may serve either as a giant conduit supplying large amounts of water to wells which tap it, or it may become clogged with clay so that a well penetrating the limestone at this point would appear to pass through two limestones and an intervening clay or shale bed. An example of a well penetrating such a clay-filled opening is given in the following driller's log of well Bt-66:

	Thickness (in feet)
Illinoian Till	
Clay	5
Vanport Limestone	
Limestone	8
Clay	6
Limestone	6
Clarion Formation	
Sandstone	20
Shale	5
Coal	½
Shale or underclay	13
Homewood Formation	
Sandstone	7

Many wells along the eastern and western sides of the quadrangle have passed through the interval at which the Vanport would be expected to occur and have encountered only sandstone or sandstone and shale. Some of these wells are only a short distance from other wells or exposures where limestone of normal thickness and character is present. Discontinuities of this sort are best explained as due to removal of the limestone by erosion and subsequent deposition of the clastic material. The subject is discussed further in the section on the lower member of the Kittanning Formation.

Kittanning Formation

White, (1878, Fig. 7) defined the Kittanning Group (named from its type area at Kittanning, Pa.) as extending from the top of the Buhrstone iron ore to the top of the upper Kittanning coal. Ashley (1926, p. 27), working farther east in the Punxsutawney quadrangle, classified the Kittanning as a formation and changed its base to "* * * the base of the clay under the lower Kittanning coal * * *." The reason for Ashley's change in the base of the unit was apparently his uncertainty in identifying the Buhrstone iron ore where the Vanport was absent. He reported that the Vanport was seen at only one place. The Vanport is present throughout the Mercer quadrangle; so, White's definition of the limits of the Kittanning is used here. The unit is ranked as a formation in this report.

The Kittanning Formation is composed of 3 members: (1) the lower member, which extends from the base of the formation to the top of the lower Kittanning coal; (2) the middle member, which extends from the top of the lower Kittanning coal to the top of the middle Kittanning coal;

and (3) the upper member, which extends from the top of the middle Kittanning coal to the top of the upper Kittanning coal. Each member is a complex lithologic unit consisting of clay, shale, sandy shale, and sandstone, and represents deposition under a variety of conditions.

Williams (1959) and Ferm and Williams (1960) discussed the regional aspects of the lithofacies and biofacies of Pennsylvanian rocks, especially in the part of the Appalachian Plateau province in Pennsylvania that lies a few miles west of the Allegheny Front. The facies of the middle member of the Kittanning were described in particular, and it was pointed out that both marine and fresh-water sediments were present in the member in some exposures.

Lower member

The lower member is present throughout most of the quadrangle, although no complete section of it is exposed in one place. Information on the member must be obtained from well logs or incomplete exposures. This information shows that the member consists generally of either clayey shale or sandstone. Shaly sandstone or sandy shale facies are rare. The lower Kittanning coal is present at the top of the member.

Over much of the quadrangle the lower member consists of a bluish-gray clay shale, which is well exposed at Station 33, in Wolf Creek Township, and at Station 45, south of Jacksonville, Pa. Sandstone is present at the top of the shale at Station 45.

In the southeast corner and along the western edge of the Mercer quadrangle, a channel sandstone is present. This sandstone is exposed at Station 27, near West Liberty; Station 39, at the edge of the quadrangle, east of the boro of Slippery Rock, Pa.; Station 34, at Harlansburg, Pa.; and Station 40, at Drake, Pa. The channel form of the sandstone is defined better than in any of the other sandstones in the quadrangle, for the member overlies an excellent marker bed (Vanport Limestone), and it is easy to determine where the sandstone occupies a channel that penetrates below the base of the lower member. Locally, the channel may cut completely through the Vanport Limestone. These places are shown in Figure 7 and on the geologic map (Plate 2).

Where the sandstone cuts completely through the Vanport, its maximum thickness is uncertain because of the similarity of the sandstones in the area. For example, well La-704 penetrates 110 feet of sandstone, but it is not possible to determine whether this sandstone consists of 1 or 3 formations. The channel sandstones are shown in Plate 3.

In the northwestern part of the quadrangle, the lower member was affected during deposition by the same environmental conditions that affected the Vanport Limestone and the Clarion Formation. As exposed at Stations 23 and 28 the lower member is a dark-gray clayey shale containing many beds of flat, dark-red siderite nodules. E. G. Williams (personal communication, 1958), stated that marine fauna are present near the base of the member at these stations and are replaced in the upper part by brackish-water forms.

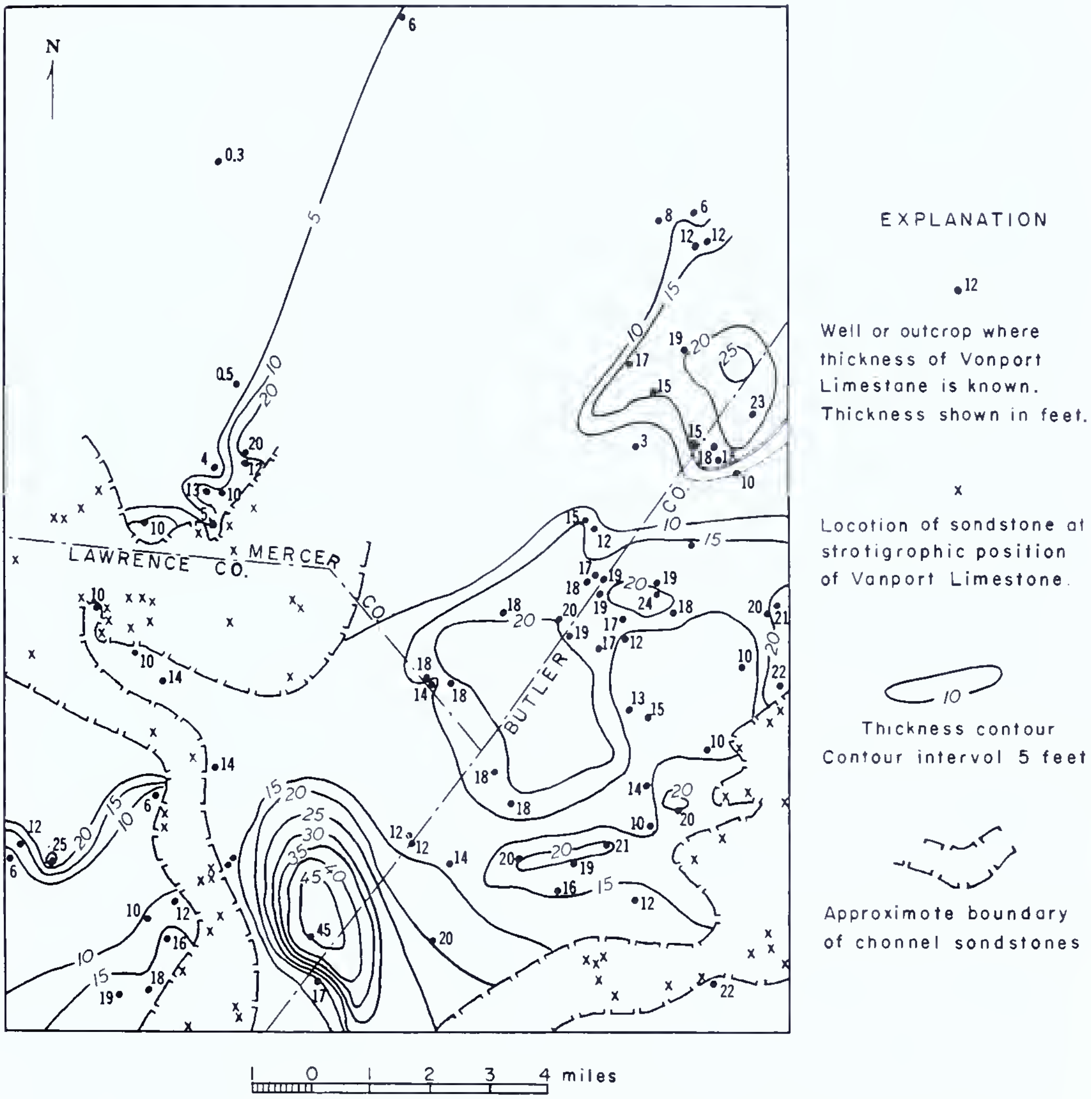

N
LAWRENCE CO.
MERCER CO.
BUTLER CO.
EXPLANATION
•12
Well or outcrop where thickness of Vanport Limestone is known. Thickness shown in feet.
x
Location of sandstone at stratigraphic position of Vanport Limestone.
10
Thickness contour
Contour interval 5 feet
Approximate boundary of channel sandstones
1 0 1 2 3 4 miles

Figure 7. Map showing thickness of the Vanport Limestone and location of channel sandstone of the lower member of the Kittanning Formation in the Mercer quadrangle.

The thickness of the member, where it does not extend below the top of the Vanport Limestone, ranges from 7 to 56 feet and averages about 30 feet. There is considerable local relief on the lower member, as shown by the exposure at Station 41, about 2 miles northeast of Harlansburg, Pa. Here the lower Kittanning coal dips eastward 16 feet in a distance of 330 feet, though it is essentially flat-lying at Station 42, a short distance away.

The lower Kittanning coal has been mined in several places in the southern half of the quadrangle, such as Stations 41-44. Its thickness in the Mercer quadrangle, ranges from 0 to 48 inches and averages about 24 inches. The thickest coal appears to occupy the area from Slippery Rock, Pa., southwestward to Ridge School.

Middle member

The middle member is present throughout most of the southern half of the quadrangle. It is much better exposed than the lower member because strip mining of the lower Kittanning coal cuts through and exposes the overlying middle member. The lithology is chiefly clay shale although sandy shale is fairly common. Sandstones are thin and of local extent. The coarsest materials in the middle member are present in the same general areas as in the lower member; that is, in the southeastern corner and along the western edge of the quadrangle. The middle Kittanning coal is present at the top of the member.

At Station 41, the exposure of the middle member consists of 18 feet of gray laminated mudstone overlain by 15 feet of gray claystone. Farther west, at Station 46, the lower Kittanning coal is overlain by 15 feet of gray thin-bedded shale and 10 feet of light-tan, clayey, fine-grained sandstone. North of Moores Corners, Pa., at Station 43, 24 feet of the middle member is exposed overlying the lower Kittanning coal. From the bottom upward, the section consists of 5 to 7 feet of dark-gray shale, 12 feet of tan, fine-grained sandstone containing a bed of crossbedded sandstone 2 feet thick, and 5 feet of tan shale. At Station 48, a short distance north of Station 43, the middle member consists of 20 to 25 feet of shale and only 2 feet of sandstone.

Plant fossils are abundant in several places in this member, such as at Station 44 and 48. The fossils were particularly well preserved at Station 44 shortly after they were exposed by strip mining. However, the shale containing them weathers rapidly and becomes crumbly after a few weeks.

The thickness of the middle Kittanning coal ranges from 5 to 48 inches and averages 29 inches.

The complete thickness of the middle member, which was measured at only eight places, ranged from 5 to 80 feet and averaged 50 feet.

Upper member

In the Mercer quadrangle, the upper member is exposed chiefly in strip mines of the middle Kittanning coal in Butler County and in southern and western Lawrence County. The lithology is coarser than in the underlying member, and sandy shale and sandstone predominate.

At Station 50, in the southeastern corner of the quadrangle. the member consists of 25 feet of gray sandstone, which intertongues with and is overlain by a gray to tan clay shale. The sandstone contains gnarled, discontinuous bands of coal 1 to 6 inches thick and fragments of plant remains. Crossbedding in the sandstone dips 20°S.26°W.

Farther north, in a strip mine at Station 51, the upper member consists of 3 feet of gray shale overlain by 5 feet of tan, massive sandstone and 5 to 10 feet of tan, thin-bedded sandstone that grades into sandy shale within a short distance. A mile to the northwest, at Station 52, the member is represented by 25 feet of dark-gray shale and 8 feet of tan shale.

At station 53, on the southcentral edge of the quadrangle, the following section is exposed in an abandoned strip mine:

	Thickness (in feet)
Kittanning Formation, upper member	
Shale, tan	12
Shale, tan, sandy; contains three fine-grained, tightly cemented sandstone beds 1 to 5 feet thick; the upper two beds grade into sandy shale, and the lowest one thickens northward, cutting irregularly into underlying shale	12
Shale, bluish-gray; locally contains a 2-inch thick coal at the top; the coal is cut out in most places by channel sandstone	3-15
Shale, dark-gray to black; contains three equally spaced beds of siderite 1-inch thick	6
Shale, black	6
Kittanning Formation, middle member	
Coal	3

At Station 54, west of Jordan School, the upper member consists of 10 to 30 feet of dark-gray, very fine-grained sandstone, containing many fragments of plant fossils. The sandstone beds are 1 to 2 inches thick.

Plant fossils are present in several exposures. However, they are invariably broken into small pieces and are usually sparse and scattered.

The upper Kittanning coal, which caps the member, is present in only a few places in the southern part of the quadrangle. The thickness of the coal was measured at Station 55, where the coal is 12 inches thick, and at Station 56, where it ranges from 12 to 36 inches thick. The thickness of the upper member at these stations was 50 and 40 feet, respectively.

Freeport Formation

The name Freeport was first used by geologists of the First Geological Survey of Pennsylvania (Rogers, 1858, p. 476) who named the sandstone that overlay the Clarion Coal Group the Freeport Sandstone. In addition, they called those sediments lying between the top of this sandstone and the base of the Mahoning Sandstone the Freeport Group. White (1878,

p. 40) defined the Freeport as a group that extended from the top of the upper Kittanning coal to the top of the upper Freeport coal. Ashley (1926, p. 27) reclassified the Freeport as a formation, but retained White's definition of its stratigraphic boundaries. Ashley's usage is retained in this report.

The Freeport Formation is divided into two members: a lower member, which extends from the top of the upper Kittanning coal to the top of the lower Freeport coal, and an upper member, which extends from the top of the lower Freeport coal to the top of the upper Freeport coal.

Lower member

The lower member is present in only a few places in the Mercer quadrangle. It is exposed at Stations 57-59 between Slippery Rock, Pa. and Forestville, Pa., where it consists of a few feet of tan sandy shale.

The lower Freeport coal, which forms the top of the member, is present only at Station 59, where the coal is 12 inches thick, and at Station 60, where it was reported to be 42 inches thick. The coal at Station 60 was covered at the time of this investigation.

Based on the difference in elevation between the lower Freeport coal at Station 60 and the upper Kittanning coal at Station 56, the lower member is about 60 feet thick in the Mercer quadrangle.

Upper member

The upper member, which extends from the top of the lower Freeport coal to the top of the upper Freeport coal, is well exposed at Station 60 only, where the following section was measured:

	Thickness (in feet)
Freeport Formation, upper member	
Sandstone, reddish-brown, medium-grained, "dirty", beds 1 to 6 inches thick, poorly exposed	10
Clay, white	1
Clay, greenish-brown	1
Clay, red	¼
Limestone, light-tan, weathers reddish-orange	1
Clay, dark-gray, silty	1
Limestone, strongly weathered	½
Clay, dark-gray, silty; contains occasional vertical bands of iron nodules	6
Siltstone, light-gray; contains poorly preserved plant fragments	½
Shale, light-gray, friable	½
Shale, black	1½
Shale, tan, clayey, friable; contains plant fragments	1½
Shale, tan, silty	2
Sandstone, tan, very fine-grained	1
Sandstone, tan, very fine-grained; becomes thinner bedded downward	1

Sandstone, tan, very fine-grained, massive	2
Shale, tan, clayey	3
Shale, dark-gray, clayey, friable; contains three siderite beds; ¼, ½, and 3 inches thick	4
Cover to floor of pit	6

The upper Freeport coal and higher beds have been removed everywhere in the Mercer quadrangle by erosion.

Quaternary System

Pleistocene Series

Previous work.—The glacial origin of the unconsolidated deposits that blanket the northwest corner of Pennsylvaina was first recognized by geologists of the Second Geological Survey of Pennsylvania (for example, White 1879, 1880). Much work has been done on these deposits since that time. Especially notable is the work of Leverett (1902, 1934) who delineated the preglacial drainage pattern and the sequence of changes that brought about the present stream system.

All of the Mercer quadrangle except the extreme southeast corner is covered by glacial deposits. In recent years this area has been studied by Preston (1950), Sitler (1957), and Shepps and others (1959). The last two authors showed that the deposits were laid down during the Illinoian Glaciation and during the early Cary Stade of the Wisconsin Glaciation. The areal distribution of these sediments, according to Sitler, is shown in Plate 1.

The Illinoian deposits have been divided into an outer and an inner phase (Shepps and others, 1959, p. 20-21). The outer phase consists chiefly of quartzite erratics and, rarely, of thin patches of highly weathered till and gravel. Sitler (1957, p. 30-35) found the outer phase underlying the inner phase in some coal strip mines near Slippery Rock, Pa. The inner phase is a fairly continuous silt or clayey silt till 5 to 10 feet thick. The phases are not differentiated in Plate 1.

The deposits of Wisconsin age in the Mercer quadrangle were laid down in association with the Kent ice advance, in early Cary time. The name Kent is derived from the city of Kent, Ohio, where these deposits are well exposed (Shepps and others, 1959, p. 31). The deposits include end moraine, ground moraine, and outwash deposits—such as kames, kame terraces, crevasse fillings, eskers, valley trains, and lake sediments. The kames, kame terraces, crevasse fillings, eskers, and valley trains are grouped as glaciofluvial deposits in Plate 1; the lake sediments are not shown.

The Kent end moraine ranges from loam till to sandy loam till. In places, constructional mounds composed of sand and gravel are well developed. Where these mounds are present the moraine is referred to as a kame moraine. In general, the moraine becomes coarser textured toward the glacial border. Swampy areas are common.

The Kent ground moraine is composed chiefly of loam till, but small pockets of glaciofluvial material are present locally. The ground moraine is characterized generally by a smooth surface without undrained depressions.

The Kent outwash, composed of sand and gravel, are common in valleys and along valley walls, but are rare on flat uplands.

Preston (1950) showed that the advance of the glacier resulted in the ponding of north-flowing streams in the Mercer and adjacent quadrangles. Initially, a single large lake (Lake Arthur) covered a major part of the Mercer quadrangle. However, as the Kent ice reached its point of maximum advance, this lake was reduced in size and split into two lakes: Lake Edmund, which occupied the drainage basin of Slippery Rock Creek, and Lake Watts, which occupied the drainage basin of Muddy Creek. These two lakes became filled with material from the glacier. Gravel was deposited near the west end of Lake Edmund, and sand was deposited farther east. The sediments of Lake Watts, on the other hand, consist chiefly of fine sand, silt, and clay, but a small amount of sand and pea-sized gravel is present at the west end of the lake. Because of the areal distribution of these sediments, Preston suggested that most of the water and sediments in Lake Watts were derived from overflow from Lake Edmund. The relationships are shown in Figure 8.

Present work.—In this investigation, study of the glacial sediments was limited to the collection of data on their thickness and (wherever possible) lithology as obtained from well logs. Thickness data were fairly easily obtained except in the deep valleys, and they have been used in the construction of the bedrock contour map. (See Plate 2.)

Well data show that the unconsolidated rocks in areas mapped as Illinoian are generally less than 25 feet thick. In areas of Kent ground moraine, the thickness of unconsolidated sediments is generally 25 feet or less, but it may be much thicker—as in the area west of Slippery Rock, Pa. and in Plain Grove Township. The thickness of the Kent end moraine generally ranges from 50 to 100 feet and may reach 200 feet—as in Plain Grove Township. Along the glacial border the end moraine is generally less than 25 feet thick. The Kent outwash is generally more than 100 feet thick.

The anomalously large thickness of end moraine and ground moraine in certain areas call attention to the fact that a map of glacial sediments is a map of surface materials only and, as such, records only the latest

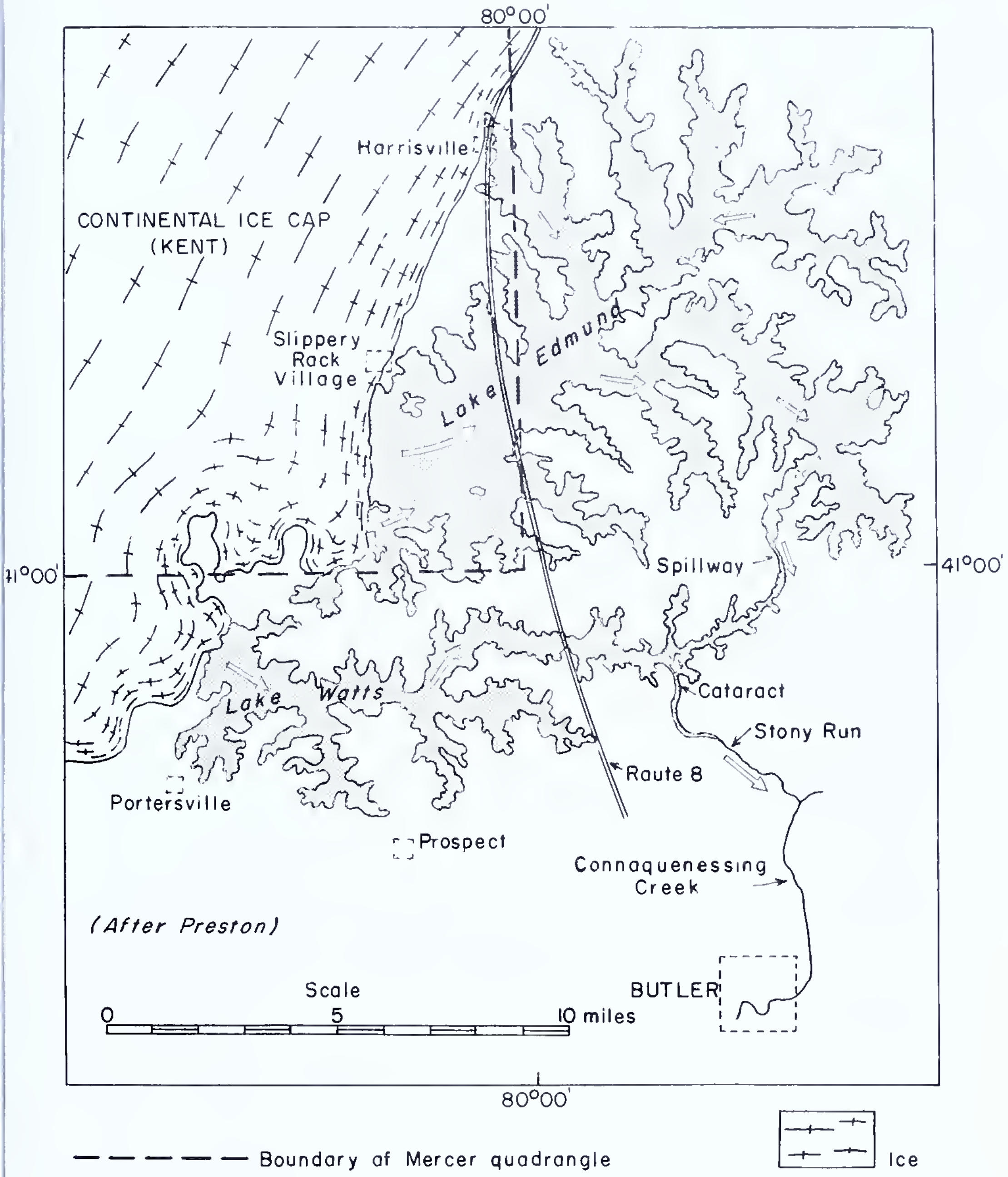


Figure 8. Map of a part of northwestern Pennsylvania, showing distribution of glacial Lake Watts and Lake Edmund in front of the Kent ice sheet (after Preston, 1950).

in a long, complex series of events. The surficial deposits, for example, give no indication of the deep bedrock trench that extends southwestward across the quadrangle. (See Plate 3.) It seems reasonable to suppose, therefore, that these unusual thicknesses occur at places where the surface material is deposited over Quaternary sediments of different character and, probably, of different origin. The available well logs confirm this interpretation.

The following information was obtained from logs of wells in areas mapped as ground moraine: Well Bt-83 penetrated 95 feet of "running sand and gravel"; well Mr-4 penetrated 78 feet of "quicksand"; and well Mr-1163 encountered 22 feet of clay overlying 2 feet of boulders and gravel and 8 feet of cemented sand and gravel.

The following information, obtained from logs of end moraine, also shows a wide variation in the type of Quaternary deposits at any one location: Well La-111 penetrated 80 feet of gravel; well La-730 hit gravel beneath 75 feet of "blue muck"; well Mr-778 encountered muck beneath 40 feet of gravel; well Mr-819, in an area mapped as Recent, penetrated 45 feet of gray pebbly silt, 20 feet of sand and gravel, and 10 feet of sandy, pebbly silt; the pebbles were made up of shale pieces and were largest in the bottom layer.

Drillers do not generally make detailed descriptions of glacial deposits penetrated by wells. Only terms summarizing the gross aspect of the lithology of the glacial sediments in the well are usually employed—such as gravel, sand and gravel, quicksand, clay, or clay and stones. Occasionally a sharp contrast in lithology is noted, as when a well penetrates two gravels separated by a clay; even so, only the total thickness is recorded.

Detailed driller's logs of the glacial material were available from a few wells. Well Bt-86 in Slippery Rock, Pa., penetrated Illinoian Till. The log follows:

	Thickness (in feet)
Illinoian deposits	
Clay, tan, soft	4
Sand, very soft and wet; contains small stones	5
Stones, small, and a trace of clay	8
Clay, dark-gray, stiff, wet	4
Clay, light-gray, stiff, moist	12
Clay, tan, soft, moist	9
Kittanning Formation, lower member	
Rock, brown, broken	—

Well Mr-1159, north of Grove City, Pa., is near the contact of ground moraine, end moraine, and glaciofluvial deposits. The log follows:

	Thickness (in feet)
Kent end moraine	
Clay and gravel, brown	30
Clay, blue, sandy; gravel	3
Clay, brown; gravel	52
Sand, brown, hard	23
Connoquenessing Formation, upper member	
Sandstone, brown and white	—

Well La-533, south of Plain Grove, Pa., is on an outwash terrace near the west end of glacial Lake Edmund. The log follows:

	Thickness (in feet)
Kent outwash	
Top soil	1
Clay, yellow	3
Sand, clay, and gravel	12
Clay, blue	12
Sand	24
Quicksand	27
Silt	12
Sand, gravel, and clay	10
Sand	35
Connoquenessing Formation, upper member	
Sandstone, white	—

PETROGRAPHY

A petrographic study of the rocks of the Mercer quadrangle is beyond the scope of this investigation. However, Hendrix (1957) studied the sandstone phases of the Homewood and Connoquenessing Formations in the Mercer quadrangle. This section summarizes his results.

He found that the percentage of heavy minerals present in both formations ranges from 0.05 to 7.8 and averages 0.8. They include a very stable suite of minerals: leucoxene (which may constitute as much as 99 percent of some samples), rutile, anatase, ilmenite, titanite (trace), tourmaline, zircon, apatite, garnet, and chlorite. Zircon and tourmaline are the only heavy minerals other than leucoxene that are present in significant amounts. Hendrix stated that their ratio can be used to distinguish the Homewood from the Connoquenessing, as zircon predominates over tourmaline in the Homewood, and the reverse is true in the Connoquenessing. The ratio is unaffected by the grain size of the minerals, but a sample representing the complete thickness of each formation must be used in obtaining the ratio.

Light minerals include quartz, orthoclase, plagioclase, muscovite, chert, and clay minerals. The quartz content of the sandstones ranges from 60-95 percent, averages about 90 percent, and is somewhat more abundant in the Homewood. The quartz grains fit together in a well-developed mosaic or interlocking texture, and nearly every grain shows evidence of solution or secondary enlargement. The formations are not tightly cemented, however, because of a film of iron oxide and/or clay between the grains. This film acts also to reduce the porosity of the rock, which was noted in some thin sections to be as little as 5 percent. The iron oxide and clay are slightly more abundant in the Connoquenessing.

Both sandstones are well sorted. The grain size of the Homewood ranges from 0.182 to 1.34 mm. (millimeters) and averages 0.362 mm The grain size of the Connoquenessing ranges from 0.175 to 0.43 mm. and averages 0.289 mm.

STRUCTURE

The Mercer quadrangle is on the western side of a broad, spoon-shaped synclinorium that lies between the Cincinnati Arch and the Allegheny Front in the Appalachian Plateau. The axis of this structure which is called the Pittsburgh-Huntington Basin, extends southwestward through Pittsburgh, Pa. The basin is characterized by many secondary flexures, which decrease in size and number westward from the Allegheny Front. (See Richardson, 1938, p. 543-554.)

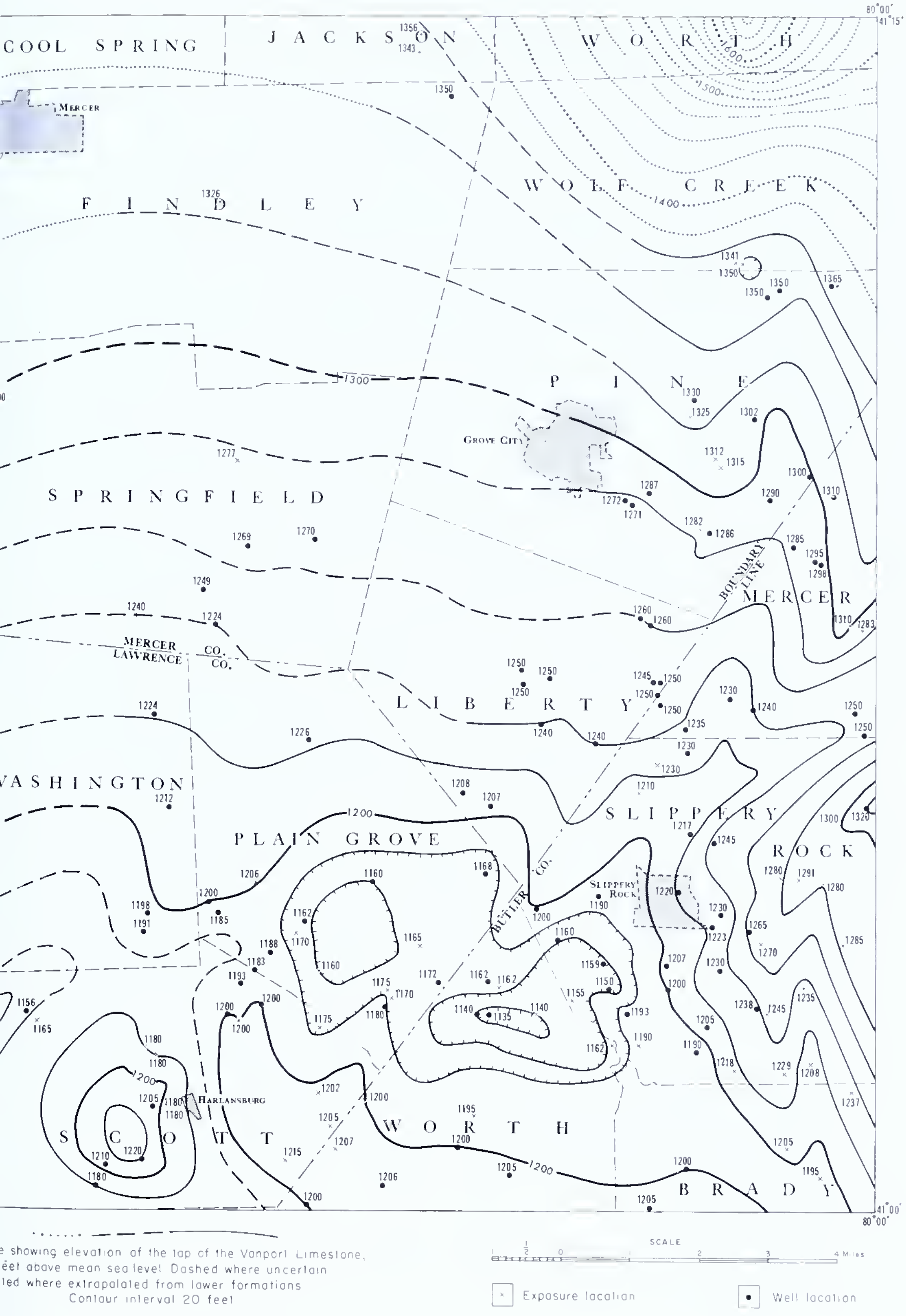
Structure contours on the top of the Vanport Limestone in the Mercer quadrangle are shown in Figure 9. The Vanport was selected because it is easily recognized by geologists and laymen (even in drill holes) throughout most of its extent. Because of this characteristic of the Vanport, information is available from local residents. Where the formation is absent, in the northern part of the quadrangle, its theoretical elevation is estimated from that of lower formations that are present. The contours based on such estimates are dashed.

The map shows a southward regional dip of about 14 feet per mile A number of smaller folds are superimposed on the regional structure A southwestward-plunging syncline and a small dome having a closure of about 40 feet are present in the southwest corner of the quadrangle

In the southcentral part, an irregularly shaped basin is divided into two parts by a low flexure near the Lawrence-Butler County line. The eastern part of the basin is deepest and rises northeastward in a narrow syncline. Between Redmond and Armstrong, Pa., the syncline splits in two; one part continues northeastward, and the other trends generally north, disappearing in the vicinity of the Henderson Dome in the northeast part of the quadrangle.

Fettke (1954, p. 8-9) states that the Henderson Dome is roughly circular, about 5 miles in diameter, and has a closure on the Homewood Formation of about 150 feet. He believes it to have been caused by a diapiric intrusion of Reedsville Shale (Ordovician), which pushed aside the Queenston and Albion Formations (Ordovician and Silurian).

A narrow anticline extends along the west side of the northward-trending syncline. West of this anticline data are sparse but only broad gentle undulations are probably present in the Mercer-County part of the quadrangle. However, in the southeast corner of the Mercer quadrangle, the Vanport rises irregularly (from the basin mentioned above) in another anticline. This anticline may possibly be the northeast extension of DeWolf's Homewood anticline (DeWolf, 1929, p. 67).



e showing elevation of the top of the Vonport Limestone,
feet above mean sea level Dashed where uncertain
ted where extrapolated from lower formations
Contour interval 20 feet

× Exposure location

• Well location

Figure 9. Map showing structure contours on the top of the Vonport Limestone in the Mercer quadrangle.

In the section on stratigraphy, attention was called to the presence of thick sections of shale in certain parts of the quadrangle. Sandstones were either much thinner or absent in these places. Excellent examples are furnished by the log of well Bt-158 and by Plate 3. Areas underlain predominantly by shale correspond closely to areas of structural lows. It seems reasonable, therefore, to suppose that the structural basins and synclines are due in large part to compaction of the shale. The converse of this theory—that structural highs coincide with thick sandstones—is difficult to demonstrate because of the scarcity of data on the Vanport or other satisfactory marker beds in areas of thick sandstone. Also, where structural control is available, stratigraphic information is lacking.

Joints.—Fractures, or planes along which a rock is broken, are called joints if no discernible movement has taken place. If it can be shown that differential movement between the two sides of a fracture has taken place, the fracture is called a fault. No evidence of faulting was obtained.

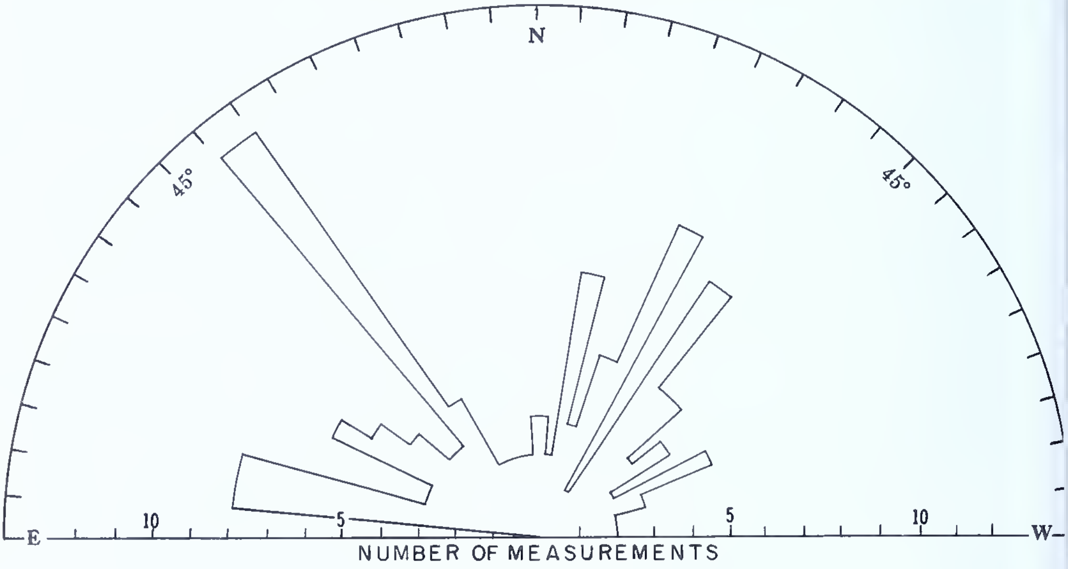


Figure 10. Diagram showing orientation of 145 joints.

Measurements of 145 joints were made at outcrops throughout the quadrangle. The joints were vertical or nearly so; their direction of orientation is shown in Figure 10. Certain preferred orientations are evident. In the northwest quadrant the commonest orientation is between N.35°W. and N.40°W. The next commonest orientation is between N.75°W. and N.85°W. Joint orientations in the northeast quadrant are more evenly distributed. The commonest orientation is N.25°-30°E., and other common orientations are N.10°-15°E. and N.35°-40°E.

A striking parallelism exists between the orientation of most of the major stream valleys and the orientation of the most prominent joint directions in each quadrant. The main valley, which cuts through the central part of the quadrangle, strikes N.26°E. for a large part of its reach. Its main tributary valleys, which enter from the west, have strikes which range from N.30°W. to N.40°W.

Such close agreement between joint directions and the orientation of major valleys suggests that the valleys may be joint-controlled. If such control does exist, it would probably be exerted not by a single joint but by a joint zone, or zone in which the density of fractures was greater than in adjacent areas. Such a concentration of fractures would constitute a zone of weakness, which would be more readily eroded than adjacent areas. The boundaries of the zone are probably not sharply delimited; rather, the density of fractures probably decreases gradually away from the center zone. Such a condition would result in increased permeability of the rocks in the valley and in the areas adjacent to the valley. Permeabilities would be expected to decrease with increasing distance from major valleys. This theory is supported somewhat by hydrologic and geochemical evidence and will be discussed further in those sections.

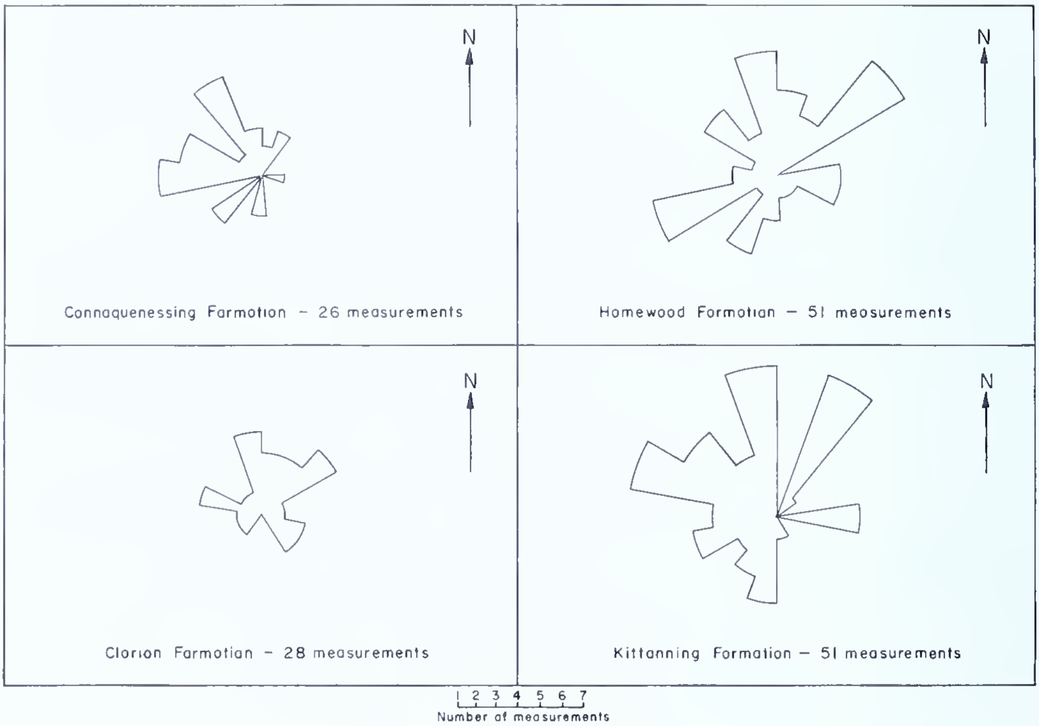
SEDIMENTATION

The rocks that have been described in the previous sections are a sample of the sediments deposited in the Appalachian Basin during Early Mississippian and Middle Pennsylvanian time. Certain interpretations may be made from this sample, although a precise delineation of the paleogeography is not possible.

Source of sediments.—The Shenango and Burgoon Formations increase both in thickness and in sand content toward the southeast in the Mercer quadrangle. The upper part of the Burgoon becomes shaly northward and appears to interfinger with the Hempfield Shale. These features suggest that the source of these Mississippian formations lay to the southeast and south of the Mercer quadrangle.

The red beds of the Upper Mississippian Mauch Chunk Formation are believed to have been removed by erosion in Early and Middle Pennsylvanian time (Butts, 1908, p. 194), so that the next younger formation in the area is the Sharon Formation of Pennsylvanian age. The presence of the Sharon in only the northwestern corner of the area, plus the studies of Fuller (1955) and other workers, indicate that the Sharon had a northern source.

Evidence concerning the source of the sediments in the remainder of the formations of the Pottsville and Allegheny Groups was obtained almost solely from measurements of the direction of dip of crossbedding



Connoquenessing Formation – 26 measurements

Homewood Formation – 51 measurements

Clarion Formation – 28 measurements

Kittanning Formation – 51 measurements

Figure 11. Diagram showing the dip directions of crossbeds in the Connoquenessing, Homewood, Clarion, and Kittanning Formations.

in sandstones. (See Fig. 11.) Crossbedding is scarce in the Connoquenessing Formation, but the measurements of dip directions that were obtained show that the crossbedding dips chiefly toward the northwest. Crossbedding is common in the Homewood Formation. The dispersion of the directions of dip is very great, however, and this is shown in Figure 11. Sandstone is not widely distributed in the Clarion Formation. Even where present, the sandstone beds are generally planar. Crossbedding is most abundant in the northeastern part of the quadrangle, and it shows that the source was generally from the south and southwest. Measurements of the dip directions of crossbedding were obtained in all three members of the Kittanning Formation, although most of the measurements were made on the lower member. They indicate that the source of the sediments was generally from the east.

Depositional site.—Evidence of the environmental conditions at the place of deposition are obtained both from fossils and from the sediments.

Marine fossils (chiefly brachiopods) are present in several formations. White (1880, p. 78-79) reported their presence in the Shenango and Hempfield Formations at outcrops in Crawford County. In the Mercer quadrangle, marine fossils are present in the Mercer limestone bed and the adjacent shale, and the Vanport Limestone.

Most of the Pennsylvanian formations contain coal beds, which indicate deposition in fresh-water swamps. (See Weller, 1960, p. 177.)

Carbonized remains of leaves and small stems are found in some of the shales. Where the leaves are found unbroken, as in the shale overlying the lower Kittanning coal, they were probably carried only a short distance and were deposited in quiet water. In contrast, finely macerated plants, such as those in the shale overlying the middle Kittanning coal, were probably transported a considerable distance. During transit the plant may have been partly decomposed, facilitating its fragmentation and wide dissemination in the shale.

The occurrence of plant remains suggests the presence of reducing conditions at the place of deposition. Additional evidence of a reducing environment is furnished by the presence of iron sulfides. The sulfides occur both in veins in the coal and disseminated through the carbonaceous shales. Such an environment prevailed in the northwestern part of the quadrangle during Clarion, Vanport, and early Kittanning times.

The nature of the site of deposition is suggested also by such features of the sedimentary body as its size, shape, configuration, and bedding. Extensive bodies of sand of fairly uniform thickness and bedding, such as the sandstone of the Shenango Formation, are commonly marine. Formations such as the Burgoon, which are of limited areal extent and have a pronounced wedge shape, suggest deposition in a deltaic environment. A fluvial environment is inferred for the sandstones of the Homewood, Clarion, and Kittanning Formations because they are narrow, elongate bodies having channel-type cross sections, and, frequently, prominent crossbedding. The sandstone members of the Connoquenessing, however, appear to have been deposited on an essentially flat surface and, locally, to have thickened upward into ridges—as in an offshore bar. Crossbedding is not common in the Connoquenessing.

Tectonism.—Sedimentary evidence of crustal movements in the Mercer quadrangle is obtained both from the succession of facies and from the suites of minerals present in the rocks. The few facies and the suite of stable minerals present in the part of the Mississippian rocks discussed in this report suggests that stable conditions prevailed during their deposition. It is possible, however, that the Mercer quadrangle is so situated in relation to the shoreline of that time that the results of minor crustal movements were not recorded in the sediments of the Mercer quadrangle. The uplift that occurred at the end of Mississippian time, and at the beginning of Pennsylvanian time, was mild and resulted in little more than a gently southward tilting and subsequent beveling of the beds in this quadrangle.

Evidence of slight crustal movements is recorded in the Pottsville sediments, although it is uncertain whether the sedimentary sequences were produced by sediments being supplied at a variable rate to a basin that was subsiding uniformly, or by sediments supplied at a constant rate to a basin whose rate of subsidence fluctuated. In the Mercer Formation, marine limestone overlies coal at two horizons and is overlain by a third coal—showing that environmental conditions changed twice from fresh water to marine and back to fresh water again. Similar evidence of oscillation is present in the sequence of formations from the Clarion Formation to the Kittanning Formation. Less dramatic (but just as indicative of movement), are the various other repetitive sequences of sediments.

The deep channels eroded in Homewood and early Kittanning time are believed to have been initiated by uplift farther upstream, although a change in climate or a diversion of the main stream from some other area to that of the Mercer quadrangle might produce similar results.

The detrital minerals of the Mississippian and Pottsville rocks are well rounded and well sorted and are stable in a near-surface environment. Apparently they have undergone considerable weathering under near-surface conditions, which indicates either that they were weathered during a period of coastal stability or that they have passed through several cycles of sedimentation. In contrast, the rocks of the Allegheny Group are composed largely of angular to subangular, poorly sorted minerals. Clay is much more abundant in sandstones of the Allegheny Group than in the sandstones of older units. Less stable minerals, such as ferromagnesian minerals, are more abundant than they are in the older rocks. In short, uplift and renewed erosion probably took place in the source areas during Allegheny time.

Geologic History.—The sedimentary record in the Mercer quadrangle indicates that during Mississippian and Pennsylvanian times deltas grew northward and westward in the quadrangle. In both periods, the sediments grade upward stratigraphically from marine toward terrestrial types. Many reversals of trend are apparent, although they are of short duration.

At the close of the Mississippian Period, the land was uplifted and tilted southward. Part of the record of Mississippian sedimentation was destroyed by the ensuing erosion. The record that is preserved shows that the Mississippian delta did not extend as far into the Mercer quadrangle as did the Pennsylvanian delta.

After a period of erosion in Early Pennsylvanian time, submergence took place, and the land was gently tilted northward. The first Pennsylvanian sediments to be deposited were the fluvial sands of the Sharon Formation, which were derived from a northern source. (See Fuller, 1955.) As the tilting continued, the Sharon delta foundered, and all sediments deposited subsequently in the area were derived from the south, southeast, or east.

In early Pottsville time, marine conditions predominated in the Mercer quadrangle, although coal in the middle member of the Connoquenessing Formation and in the Mercer Formation indicates that the area was above water several times. Following the deposition of the Mercer Formation, the area was uplifted and deep channels were cut. The Homewood Formation was deposited in these channels. Erosion changed to alluviation during late Homewood time as shown by the presence of shaly sandstone at the top of the formation. A period of quiescence followed, during which the Brookville underclay and coal accumulated.

Further deltaic growth occurred during Clarion time and was followed by land submergence and the deposition of the marine Vanport Limestone.

Uplift and erosion similar to that of early Homewood time then took place, and deep channels were scoured. Sandstone of the lower member of the Kittanning Formation was deposited in these channels, and a period of coal formation followed.

The lithology of the middle member of the Kittanning Formation in the Mercer quadrangle does not show definitely whether the member is a marine or fresh-water deposit. The plant material in the member is severely macerated, which suggests that it was transported a considerable distance before it was deposited. Moreover, E. G. Williams (1959, personal communications) found marine fossils in this member a few miles south of the Mercer quadrangle.

The remainder of the Allegheny Group is characterized by deposits of coal, small channel sands, and shales.

GROUND-WATER HYDROLOGY

PRINCIPLES OF OCCURRENCE

Precipitation that falls on the earth's surface may be returned directly to the atmosphere by evaporation; it may move by overland flow to streams and be lost to the area by surface runoff; or it may percolate downward into the earth through pores and fractures in the soil and rocks. Some of the water that enters the earth may be captured by plants; some may be adsorbed on soil or rock particles; and some may continue to move downward until it reaches the zone of saturation, within which all pores and fractures are filled completely with water under pressure greater than atmospheric. Water within this zone is called ground water, and its upper surface is called the water table.

Water in the zone of saturation continues to move, under the influence of gravity, from areas of intake or recharge to lower levels and finally to points of discharge. The water moves in the direction of the greatest hydraulic gradient, which is defined as the difference in hydraulic head between two points divided by the flow distance between them. The rate of movement of the water is a function of the hydraulic gradient and the size and degree of interconnection of the openings in the rocks. Because most of the openings are small, they offer considerable resistance to the flow of water, so that ground water usually moves at rates of only a few feet per day or even per year. The ability of a rock to transmit water is referred to as its permeability, which is expressed as the amount of water in gallons per day that can be transmitted through a cross-sectional area of 1 square foot under a unit hydraulic gradient. A rock that yields sufficient water to make it an economic source of supply is called an aquifer.

Ground water may occur under either water-table or artesian conditions. Under water-table conditions the ground water is not confined, and the water table is free to fluctuate in response to recharge, discharge, and changes of barometric pressure. The configuration of this surface is generally a subdued replica of the land surface.

Under artesian conditions there is no water table, for the ground water is confined under hydrostatic pressure between less permeable beds, and the water level in a tightly cased well tapping the artesian aquifer will rise above the top of the aquifer. The imaginary surface to which the water will rise in wells tapping an artesian aquifer is called the piezometric surface.

GROUND-WATER FLUCTUATIONS

Ground-water levels are not static; they fluctuate in response to changes in barometric pressure and in the recharge-discharge regimen. The amount of recharge reaching an aquifer under natural conditions depends not only on the amount of precipitation but also on its intensity and distribution throughout the year, the temperature of the air and soil, and the type and amount of vegetation. The amount of water discharged from an aquifer under natural conditions is equal to the recharge. The discharge is accomplished by flow to surface-water bodies or to other aquifers having lower hydraulic head, by direct evaporation from the water surface, and by transpiration by plants. Human activities, of course, can effect major changes in this regimen.

Because the regimen varies somewhat from year to year, the water level will change in response to these long-term variations. Thus, it will stand somewhat higher in wet years and lower in dry years.

Water levels were measured periodically in approximately 100 observation wells in the Mercer quadrangle during 1957. Water-level recorders were installed on 12 wells, to furnish continuous measurements, and monthly measurements were made on the remainder of the wells. Figure 12 shows water-level fluctuations in well Mr-526, and the records of temperature and precipitation at the U. S. Weather Bureau Station at Slippery Rock, Pa.

Precipitation is fairly uniformly distributed throughout the year, although it is slightly greater during the summer months. Water levels in most of the observation wells were highest in April. They declined during the summer to a low in October or November. This period of decline corresponds to the growing season, and the decline in water levels at this time shows that most of the rain was being intercepted by plants.

The highest and lowest points in the cycle occur at about the same time in all wells regardless of the depth to water, showing that there is no detectable delay in the response to surface influences in any of the aquifers measured, regardless of their depth.

The fluctuations of the water levels in the observation wells during the year 1957 ranged from 0.75 to 21.2 feet. However, in about half of the wells the range of fluctuation was 6 feet or less, and in about 70 percent the range was less than 10 feet.

CIRCULATION OF GROUND WATER IN THE MERCER QUADRANGLE

The mature dissection of the bedrock surface has divided the Mercer quadrangle into a number of "hydrologic islands" a few square miles in area, each of which has its own pattern of circulation. The "islands" are made up of rocks younger than the lower member of the Connoquenessing Formation. Thus, the lower member of the Connoquenessing is the youngest unit that is hydrologically continuous over a major part of the area.

Despite the detailed well inventory, there are not sufficient data to permit the preparation of piezometric maps for the many different aquifers. Measurements of the depth to water in wells show that the water levels in the individual formations rise above the tops of their formations, indicating artesian conditions. However, water levels in a formation stand at a higher elevation beneath a topographic high than beneath a valley—showing conformance to the topographic surface such as occurs under water-table conditions. The anomaly is believed to be caused by fractures, or other zones of high permeability in the overlying confining beds, which permit the downward movement of considerable amounts of water through the overlying beds. Some of this water discharges where the aquifers outcrop around the margins of the "hydrologic islands." The rest of the water moves downward to lower aquifers.

Observations of drillers support the above interpretation: In some wells the static water level is reported to change less than 1 foot as the well is drilled through successively deeper aquifers; elsewhere, a decline in head of as much as several tens of feet is reported as deeper aquifers are penetrated.

The circulation pattern of water in the glacial material is similar to that in the bedrock. Water is derived both from precipitation on the surface and from discharge from subcrop areas of the bedrock. Surface streams serve as places of discharge for the glacial materials.

The pattern of flow through an idealized cross section of the complex environment described above is shown in Figure 13. Confirmatory evidence of this pattern is supplied also by the chemical quality of the water, especially in the glacial sediments. For further discussion, see the section on geochemistry.

Marked changes in head will occur as deeper aquifers are penetrated, except in places where the rocks are severely fractured. Except in valleys, the head will decline as wells are deepened, indicating that water is flowing from upper aquifers to lower aquifers via the borehole. Work by Bennett and Patten (1960) on well Mr-526 showed internal discharge of water from the upper aquifer to a lower aquifer. They point out that because of this internal circulation the well would have to be pumped at a rate greater than 500 gpm before the lower aquifer would yield any water to the well.

The rate at which a multiaquifer well would have to be pumped to obtain the maximum yield from each aquifer would depend on the characteristics of each aquifer and on the differences in head between aquifers.

In a valley, the pattern of circulation may be such as to produce a flowing well. The maximum amount of water obtainable from such a well can be determined only by an evaluation of each aquifer tapped by the well.

Avenues of movement.—The permeability of unconsolidated materials is controlled by the size, shape, sorting, and packing of the component grains. Thus, a well-sorted sand composed of well-rounded grains is highly permeable, and a clay is relatively impermeable. The consolidated equivalents of these materials (sandstone and shale) are generally considered in the same way. Such a generalization may be erroneous for two reasons: first, the presence of cement reduces the permeability of the sandstone, possibly even to zero; and second, the cementation of the sediments prevents free intergranular movement in response to stresses in the earth's crust and results in the development of joints and other fractures in the rock, which are referred to as secondary openings.

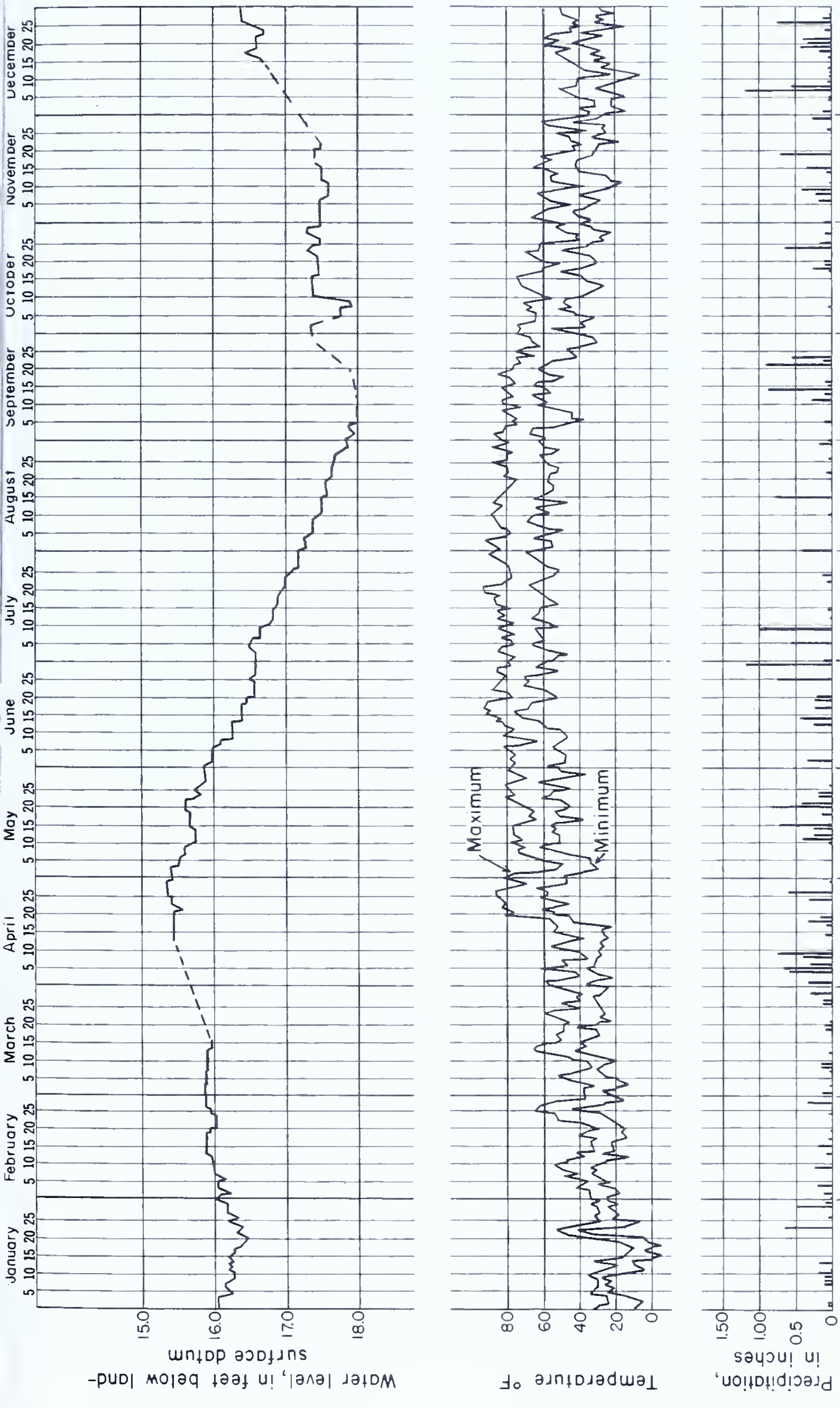


Figure 12. Graph showing fluctuations of the water level in well Mr-526, and the daily temperature and precipitation at the U. S. Weather Bureau Station at Slippery Rock, Pa. in 1957.

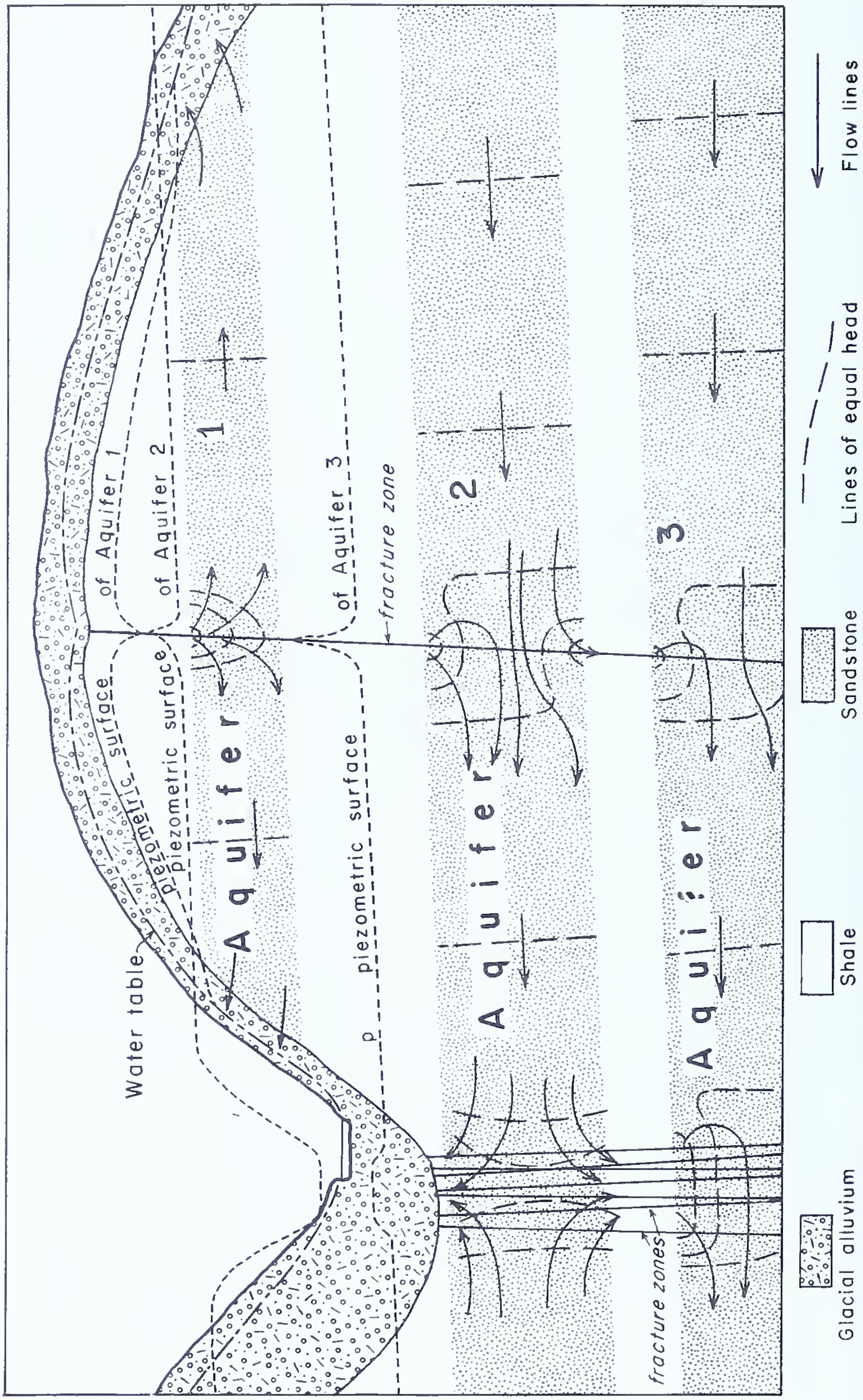


Figure 13. Idealized pattern of ground-water flow in the Mercer quadrangle.

In the Mercer quadrangle the cementing material that binds the grains of sand together is chiefly silica, but it may contain minor amounts of clay minerals and compounds of iron. The cement differs in amount from place to place between formations and within one formation. The range in degree of cementation in a formation, as shown by the sample logs of wells such as Bt-19 and Mr-1184, has already been noted in the section on stratigraphy.

The exact cause of the irregular distribution of cement is uncertain, but, the effectiveness of the cement in impeding the flow of ground water is shown in a spectacular manner in wells at Grove City.

These wells are approximately 300 feet deep and penetrate bedrock formations extending from the Burgoon Sandstone to the lower part of the Homewood Formation. Most of the wells are cased to the top of the Connoquenessing Formation, so that about 180 feet of sandstone, broken by only a few thin beds of shale, are exposed in each well. Well Mr-948, however, is cased into the lower member of the Connoquenessing Formation, to a depth of 210 feet below land surface.

During the pumping of well Mr-947, several slugs of brine were introduced into well Mr-948, 113 feet away, and their movement in the well was traced with a fluid-conductivity probe. Brine placed in the interval from 264 to 286 feet below land surface moved out of the well into the aquifer—the most rapid movement taking place in the upper part of this interval. Brine placed above or below this interval remained apparently undisturbed.

Shortly after pumping stopped, water surged into well Mr-948 in the interval between 264 and 268 feet below land surface, splitting a brine slug opposite this interval into two parts and displacing one part upward and the other downward.

The tests indicate that the only permeable rocks exposed below the casing in well Mr-948 are those between 264 and 286 feet below land surface, and that the interval from 264 to 268 feet is many times more permeable than the rest of this zone.

Brine tracing was conducted also in well Mr-1168, at Grove City, Pa. The well was 305 feet deep and was cased to 116 feet below land surface. The static water level was about 40 feet below land surface. The electric log shows the same sequence of sandstone and minor shale breaks that are present at wells Mr-945 and Mr-948. Brine was injected into the well at the top and was flushed downward by a stream of water from a hydrant. The brine slug moved downward at the rate of about 30 feet per minute until it reached a depth of about 240 feet. Most of the slug left the hole between 240 and 260 feet below land surface, and the remainder continued slowly downward to about 284 feet. A slug introduced below 284 feet stagnated.

These results indicate a permeable zone from 240 to 284 feet below the land surface, and indicate also that the greatest permeability is in the upper 20 feet of the interval.

In both wells Mr-948 and Mr-1168 the permeable zone is present in the Burgoon Sandstone—not in the overlying Connoquenessing Formation. Pumping tests indicate that the permeable zone is present throughout the Grove City-Cooper-Bessemer well field and extends westward at least as far as well Mr-1131, at the edge of Grove City, Pa. The persistence of this zone over so large an area indicates that the permeability is probably due to the stratigraphy rather than to fractures, for, as noted in the section on structure, the fractures observed in the field are invariably high-angle fractures having small lateral extent.

As a possible explanation of the persistent zone of high permeability, it is suggested that the zone is probably poorly cemented because conditions at the time of sedimentation favored the deposition of coarse material. The coarse-grained sediments, in turn, have large interstices that permit rapid movement of water, which makes them unfavorable sites for the deposition of cementing material. The phenomenon is not of unlimited extent, however, for boundary conditions are indicated by pumping test data, and data on the Burgoon Sandstone from wells elsewhere in the quadrangle indicate it has low permeability at those places.

Dickey and others (1943, p. 31) noted a relationship between degree of cementation and coarseness of grain size in the oil-bearing Venango sands of Devonian age.

Several wells completed in shale in the Mercer quadrangle have reported yields that suggest the importance of fractures. For example, during a pumping test, well Bt-20 yielded 50 gpm for 20 hours from shale of the lower member of the Kittanning Formation and had only 12 feet of drawdown; also, well Mr-1162 yielded 20 gpm from shale of the Clarion Formation, and well Mr-18 yielded 25 gpm from shale of the Mercer Formation. Drawdown in the latter two wells is not known

Many wells in the Mercer quadrangle show the influence of boundary conditions when they are pumped. (See Fig. 14.) Pumping tests on the wells tapping bedrock aquifers generally indicate the presence of recharge boundaries near the wells. These recharge boundaries are believed to be areas where fractures permit recharge from overlying or underlying aquifers.

Wells producing from materials having considerable primary permeability, such as glacial deposits, can be expected to show the effects of both recharge boundaries and impermeable boundaries. In the Mercer quadrangle, some wells tapping glacial materials show sharp increases in drawdown as they are pumped at a constant rate, indicting the presence of an impermeable boundary—probably a zone of clay or clayey sand of low permeability near the well. Other wells show a decreasing rate of drawdown soon after pumping starts, indicating the presence of a recharge boundary—believed to be a zone of sand or gravel of high permeability near the well.

HYDRAULICS

Definitions and principles

Pumping tests.—The hydraulic properties of a rock are described in terms of its ability to store and transmit water. The storage capacity is expressed as a coefficient, S, defined as the volume of water that an aquifer releases or takes into storage per unit surface area per unit change in the component of head normal to that surface. For water-table conditions, S is equivalent to specific yield; that is, the volume of water that will drain by gravity from a saturated rock divided by the volume of the rock. The storage coefficient of a water-table aquifer commonly has a value between 0.05 to 0.30. Under artesian conditions, water released from or taken into storage in response to a change in head is attributed solely to the compressibility of the aquifer and the water. The compressibility of these substances is small, so that the storage coefficient of the artesian aquifer usually ranges from 0.0001 to 0.001.

The transmissibility of an aquifer is expressed as a coefficient (T), which is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer one foot wide and extending the full saturated height, under a unit hydraulic gradient, at a temperature of 60°F. Transmissibility may be changed to permeability by dividing the transmissibility by the saturated thickness of the aquifer.

The aquifer coefficients, S and T, are calculated from measurements of the discharge-drawdown relationship in the vicinity of a pumped well. As a well is pumped, a cone of depression is formed in the piezometric surface about the well. The cone expands and deepens until one of the three following conditions is met: (1) recharge to the aquifer is increased in an amount equal to the pumping rate, (2) natural discharge from the aquifer is decreased in an amount equal to the pumping rate, or (3) the sum of the increased recharge and decreased natural discharge is equal to the pumping rate.

Theis (1935, p. 519-524) developed an equation for the radial flow of water to a pumped well. It is expressed in ordinary Survey units as:

$$s = \frac{114.6Q}{T} \int_{u}^{\infty} \frac{e^{-u}}{u}\, du$$

where

s = drawdown in feet at an observation well in the vicinity of a well discharging at a constant rate

u = $1.87\ r^2\ S/Tt$

Q = discharge of well in gpm

T = transmissibility in gpd/ft

r = distance in feet from the discharging well to observation well

S = storage coefficient

t = time in days since pumping started

The value of this integral is given by an infinite series:

$$\int_{u}^{\infty} \frac{e}{u}\, du = W(u) = -0.577216 - \log_e u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3\ \ 3!} \quad \cdots\cdots$$

Tables of values of W(u) for different values of u have been prepared (Wentzel, 1942, facing p. 89). A plot of W(u) versus u on logarithmic paper is known as a type curve.

The aquifer coefficients, S and T, may be obtained by the following steps: (1) plot the drawdown in feet of either a pumped well or of an observed well, which is completely connected hydraulically to the pumped well, versus time in minutes on logarithmic graph paper; (2) fit the data curve to the type curve keeping the axes of the graphs parallel to each other, and note the drawdown-time value (match-point) at some convenient value on the type curve; then (3) solve for S and T in the following equations (Walton, 1953, p. 8):

$$S = \frac{Tu}{2692.8\,(r^2/t)}, \qquad T = \frac{114.6Q\ W(u)}{s}$$

where t is measured in minutes and the other units are as defined above.

A number of assumptions are inherent in the above computation; (1) the aquifer is considered to be homogeneous, isotropic and infinite in areal extent, (2) the pumped well penetrates the aquifer completely, (3) the coefficient of transmissibility is constant at all times and places, (4) the well has an infinitesimal diameter relative to the aquifer as a whole, and (5) water removed from storage is discharged instantaneously with decline in head. Although these conditions are seldom met completely in nature, the method has been applied successfully to many groundwater problems.

In many instances, such as in the present investigation, data can be obtained from only the pumped well. Data collected from the pumped well are apt to be less accurate than those from observation wells because

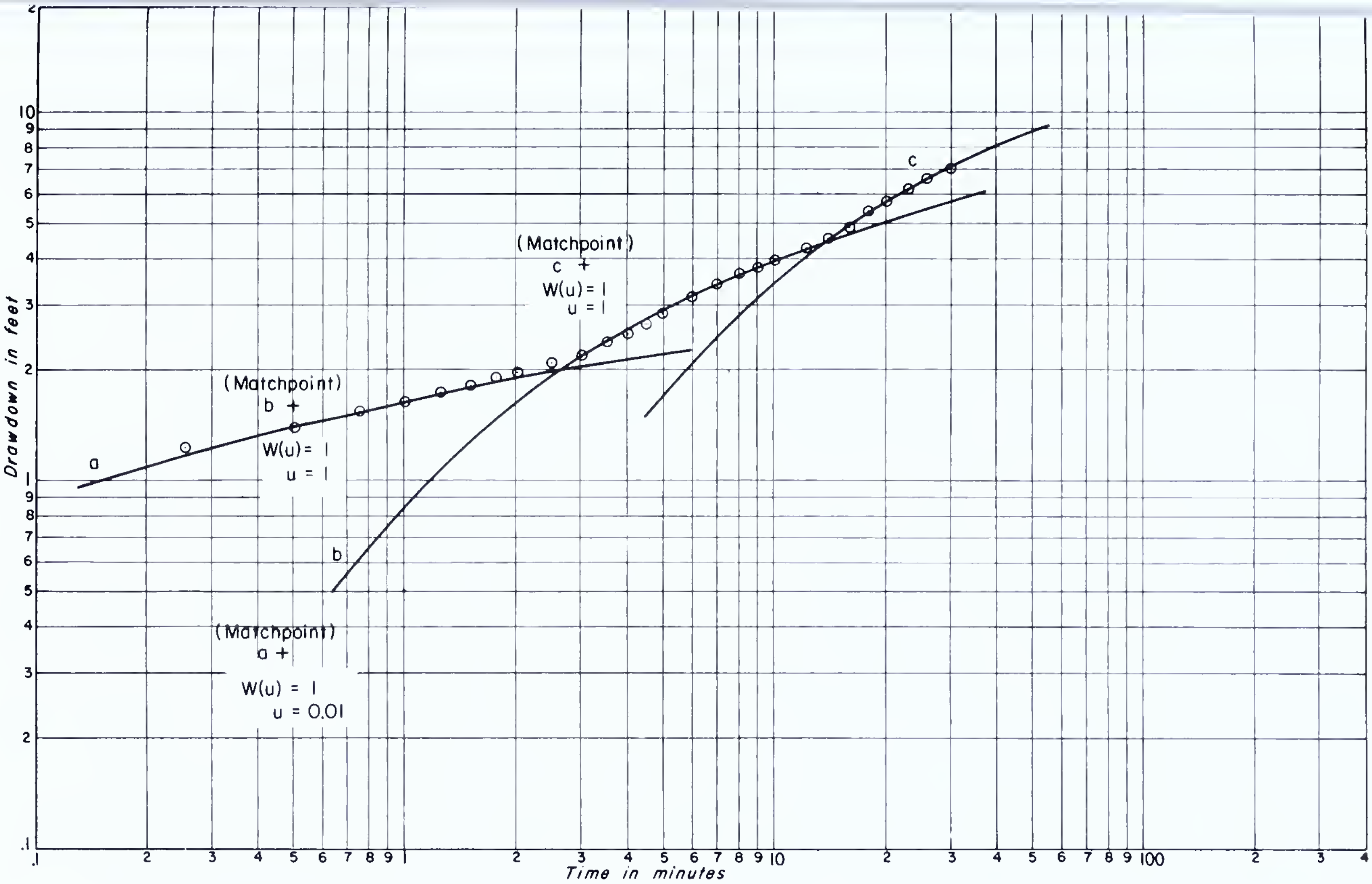


Figure 14. Graph showing drawdown in well La-485 during pumping. Lines are segments of type curve that have been fitted to data. The discontinuities indicate the presence of boundary conditions in the vicinity of the well.

of entrance losses to the pumped well. Also, it is usually impossible to determine the effective radius of the pumped well, and the storage coefficient cannot be calculated when the radius of the well is unknown. However, determinations of transmissibility are at least of the correct order of magnitude and serve as an estimate of the aquifer's capabilities.

Boundary conditions.—The data curve may match the type curve throughout only part of its extent and lie above or below the theoretical curve throughout the remainder. Where the data curve shows more than the theoretical drawdown, it indicates that the cone of depression has expanded to an impermeable boundary, which may be either a place where water is being discharged from the formation or a zone of low permeability. If the data curve shows less than the theoretical drawdown, it indicates that the cone of depression has expanded to a recharge boundary, which may be either a source of recharge to the aquifer or a zone of high permeability. Where boundary conditions are present, calculations of the aquifer coefficients are made from the early part of the curve.

If boundary conditions are simple and data are obtained from three or more observation wells, the position of the boundary may be estimated. However, because of the many boundary conditions revealed during the pumping tests, a detailed mathematical analysis seemed inappropriate even where observation wells were present. Figure 14 is a drawdown-time plot of well La-485 showing the presence of boundary conditions.

Hydrology of aquifers

Pumping tests were made on 37 wells during this investigation. In addition, Mr. T. Uber made available data on pumping tests that he had made on the Slippery Rock, Pa. wells (Bt-28 and Bt-29); and Mr. Boller, maintenance superintendent at Slippery Rock State Teachers College, furnished pumping-test data for well Bt-87.

The results of these tests are presented in Table 1. As observation wells were available for only the tests at Grove City, Pa., and Slippery Rock, Pa., the storage coefficients could be computed for only those tests.

Table 2 is a summary of drillers' tests of wells in the area. In using these tables it should be kept in mind that, except in the case of municipal and industrial wells, the wells may not penetrate the aquifer completely; many of the wells yield water from discrete zones rather than from the entire aquifer; and, within a short time after pumping is begun, the cone of influence of the well may extend to rocks that have either higher or lower permeability than those in which the well is drilled.

Despite these complex conflicting factors, the data for each formation tend to be similar. For this reason they are believed to indicate the approximate hydraulic character of the formations.

Table 1.—*Results of pumping tests.*

Aquifer	*Well no.*	*Transmissibility (T) (gpd/ft)*	*Permeability (K) (gpd/ft²)*	*Storage coefficient*
Kent end moraine	Bt-69	900	70	—
	La-116	100	1	—
	Mr-28	400	—	—
	Mr-550	2,000	40	—
	Mr-564	2,000	—	—
	Mr-588	8,000	400	—
	Mr-761	500	100	—
Kent outwash	La-130	300	4	—
	Mr-701	8,000	300	—
	Mr-752	400	3	—
Lower member of the Kittanning Formation	La-485	800	20	—
Clarion Formation	Bt-25	8,000	150	—
	Bt-52	4,000	—	—
	Bt-87	3,000	100	—
	Mr-545	400	10	—
	Mr-805	20,000	—	—
Homewood Formation	La-194	400	10	—
	Mr-42	600	20	—
	Mr-526	10,000	400	—
	Mr-546	200	10	—
	Mr-677	200	6	—
	Mr-684	2,000	—	—
	Mr-735	100	—	—
	Mr-776	400	10	—
	Mr-791	5,000	—	—
	Mr-795	500	20	—
Mercer Formation	La-117	100	5	—
Upper member of the Connoquenessing Formation	Bt-28	7,000	—	—
	Mr-19	8,000	200	—
	Mr-731	600	30	—
	Mr-812	100	5	—
	Mr-1184	4,000	20	—
Lower member of the Connoquenessing Formation	Bt-29	7,000	500	20×10^{-5}
	Mr-1184	8,000	400	—
Connoquenessing Formation, undifferentiated	Bt-13	10,000	—	—
Connoquenessing and Burgoon Formations	Mr-526	1,000	10	—
Burgoon Sandstone	Mr-379	400,000	—	20×10^{-5}
	Mr-945	100,000	—	3×10^{-5}
	Mr-946	70,000	—	8×10^{-5}
	Mr-948	100,000	—	2×10^{-6}
	Mr-949	100,000	—	3×10^{-5}
	Mr-1131	60,000	—	—

Shenango Formation.—Only one well utilizing this formation was inventoried, and no estimates of its water-bearing properties were obtained.

Hempfield Shale.—Yield data were obtained from only one well, which was reported to yield 3 gpm (gallons per minute).

Table 2.—*Summary of reported yields of wells.*

Aquifer	*Number of wells*	*Range of yields (gpm)*	*Median yield (gpm)*
Recent alluvium	3	5-80	20
Kent end moraine	8	10-18	15
Kent outwash	8	10-20	11
Kittanning Formation			
Middle member	1	—	30
Lower member (sandstone)	12	4-30	10
Lower member (shale)	6	7-50	15
Vanport Limestone	1	—	18
Clarion Formation			
Sandstone	8	8-150	15
Shale	9	3-36	15
Homewood Formation	38	6-30	20
Mercer Formation	13	2.5-125	13
Connoquenessing Formation			
Upper member	22	3-300	18
Middle member	1	—	5
Lower member	5	15-36	20
Hempfield Shale	1	—	3

Burgoon Sandstone.—In 1960, water from this formation was used in only the Grove City, Pa., area. Well Mr-947, at Grove City, was pumped at the average rate of 1,056 gpm for 4 hours and the drawdown was measured in wells Mr-379, Mr-945, Mr-946, Mr-948, and Mr-949. Coefficients of transmissibility and storage obtained from the several observation wells are shown in Table 1. Figure 15 shows a plot of the drawdown data from well Mr-949. The curve in Figure 15 is representative of the data collected at each of the wells during the test. The early data from each test were used to compute the aquifer coefficients. The locations of the wells are shown in Figure 16.

The coefficients of transmissibility obtained at four of the wells ranged from 70,000 to 100,000 gpd per ft and averaged about 90,000 gpd per ft. The coefficients of storage ranged from 2×10^{-5} to 8×10^{-5} and averaged 4×10^{-5}. The coefficients obtained at well Mr-379, however, were anomalously high ($T = 400{,}000$ gpd/ft, $S = 20 \times 10^{-5}$). The anomaly is due either to a change in the character of the aquifer in the vicinity of this well, or, more likely, to clogging of the well.

Analysis of the pumping test on well Mr-1131 gave a T of 60,000 gpd per ft and showed that the highly permeable zone present in the Grove City-Cooper-Bessemer Co. wells extends at least as far westward as the western limits of Grove City.

A pumping test of well Mr-526, 2½ miles south of the Grove City well field, show a marked decrease in the aquifer's permeability. A continuously permeable zone, comprising the Connoquenessing and the Burgoon Formations, was present at well Mr-526. The transmissibility

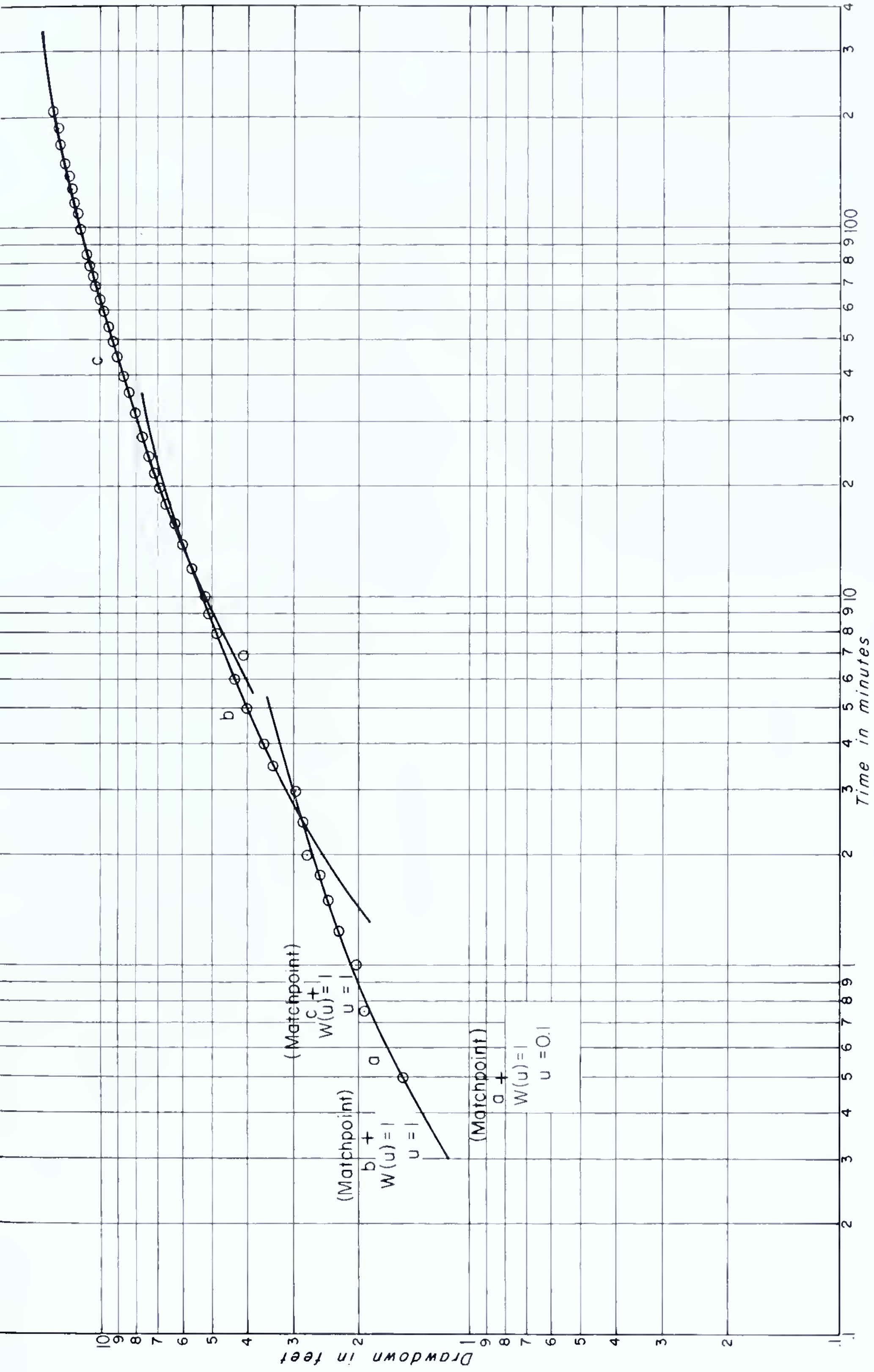


Figure 15. Graph showing drawdown in well Mr-949 during pumping. Lines are segments of type curve that have been fitted to data. The discontinuities indicate the presence of boundary conditions in the vicinity of the well.

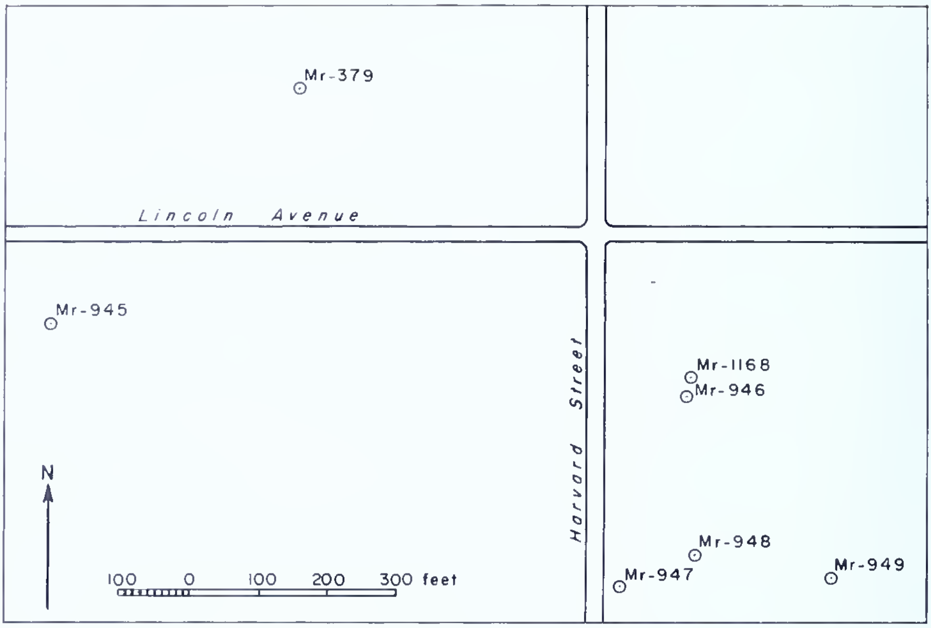


Figure 16. Map showing the location of wells in the Grove City-Cooper-Bessemer Co. well field in Grove City, Pa.

of this zone was estimated to be 1,000 gpd per ft, of which the Burgoon contributes about one-third.

Brine tracing in well Bt-25, about 6 miles south of Grove City, showed an almost imperceptible downward circulation of water from the Clarion Formation to the Burgoon Sandstone. Pumping of the well at 12 gpm (the maximum capacity of the pumping equipment available at the time) failed to disturb this pattern of internal circulation, and it was not possible, therefore, to determine the transmissibility of the Burgoon at this well.

Hydrologic information concerning the Burgoon Sandstone is not available elsewhere in the quadrangle. Further study of the Burgoon would require the drilling of new wells. Because of the large supplies available from this formation in the Grove City area, further study of this formation may well be justified as the need for water increases.

Sharon Formation.—No hydrologic information is available on this formation.

Connoquenessing Formation.—Pumping tests on 7 wells yielded transmissibilities that range from about 100 to 10,000 gpd per ft; over half of these were between 7,000 and 8,000 gpd per ft. Computed permeabilities ranged from 5 to 500 gpd per ft^2. A storage coefficient of 20×10^{-5} was obtained from the test on well Bt-29.

At well Mr-1184 transmissibilities of 4,000 gpd per ft and 8,000 gpd per ft were obtained for the upper and lower members. The formation was penetrated completely by the well. Churn-drill samples show that the upper member is composed of 19 feet of loosely cemented medium-grained quartz sand. They show also that the lower member is composed of 34 feet of fine-grained quartz sand, which is well cemented in the lower 15 feet. Brine-tracing techniques show this lower 15 feet to be relatively impermeable. Well Mr-19, about 0.3 mile southeast of well Mr-1184, penetrates 43 feet of sandstone of the Connoquenessing Formation, which has a transmissibility of 8,000 gpd per ft.

Transmissibility of the formation at wells Bt-28 and Bt-29 is 7,000 gpd per ft. Although several permeable zones were encountered in drilling well Bt-29, according to the driller's record, all of them—except one in the bottom 15 feet of the well—were cased off. Thus, the transmissibility and storage are based on only the lowest zone. At well Mr-526, 2.5 miles north of wells Bt-28 and Bt-29, a transmissibility of about 1,000 gpd per ft was obtained for the combined Connoquenessing and Burgoon Formations. At well Bt-25, 1 mile southeast of wells Bt-28 and Bt-29, the formation was shown (by brine-tracing experiments) to be relatively impermeable.

The above results show that very good agreement may be obtained for two wells that are very close together, such as wells Mr-1184 and Mr-19 or wells Bt-28 and Bt-29. However, at distances of more than 1 mile the aquifer characteristics may change greatly.

Reported yields also have a wide range. The yields ranged from 3 gpm (at unknown drawdown) to that of a well which flowed an estimated 300 gpm.

Mercer Formation.—Reported yields are available for 12 wells in the Mercer Formation. The yields range from 2.5 to 125 gpm and the median yield is 13 gpm. The amount of drawdown and duration of pumping are not known.

A pumping test was made on well La-117; the transmissibility obtained from this test was 100 gpd per ft and the permeability was 5 gpd per ft^2.

Homewood Formation.—Determinations of the transmissibility of the Homewood Formation were made at 10 wells. The transmissibility ranged from 100 to 600 gpd per ft at seven of the wells and was 2,000 gpd per ft at well Mr-684, 5,000 gpd per ft at well Mr-791, and 10,000 gpd per ft at well Mr-526. The range of permeability was narrow (6 to 20 gpd per ft^2), except at well Mr-526 where the permeability was 400 gpd per ft^2. Reported yields for 38 wells ranged from 6 to 30 gpm, except for 1 well that was reported to yield 500 gpm. The median yield reported is 20 gpm. The hydraulic properties of the Homewood, therefore, appear to be fairly uniform, suggesting that the unusually high transmissibilities may reflect local conditions that are related to the well rather than to the aquifer. One possible explanation of the few high transmissibilities could be vertical recharge (around the casing of these wells) from the overlying formations, as the Homewood is overlain at most of these wells by deposits of sand and gravel.

Clarion Formation.—Pumping tests were made on 5 wells in the Clarion Formation. The transmissibility ranged from 3,000 to 20,000 gpd per ft., except at well Mr-545 where it was 400 gpd per ft. The low transmissibility at well Mr-545 may possibly be attributed to the shaly character of the Clarion in the vicinity of this well.

It is difficult to understand why sandstone such as that in the Clarion, which is composed of angular, fine-grained quartz and an abundant clay matrix, should be a better aquifer than the sandstone of the Homewood Formation, which is made up of well rounded, medium-grained quartz and only minor amounts of clay. The best explanation seems to be that the Clarion Formation is more highly fractured than the Homewood Formation.

Reported yields are available from 18 additional wells. Half of these wells tap sandstone aquifers and the other half tap shale aquifers. The yield of wells in the sandstone ranges from 8 to 150 gpm, and the yield of wells in shale ranges from less than 3 to 36 gpm. However, wells in both rock types have a median yield of 15 gpm.

Vanport Limestone.—Hydraulic data for this formation are available from only well Bt-83, which is reported by the driller to yield 18 gpm.

Kittanning Formation.—A coefficient of transmissibility was obtained for only one well in the Kittanning Formation—well La-485, which penetrates sandstone in the lower member. The transmissibility was 800 gpd per ft.

Reported yields from driller's records are available for 18 additional wells. Yields from 11 wells penetrating sandstone range from 5 to 30 gpm; the median yield is 10 gpm. Yields from 6 wells in shale range from 7 to 50 gpm; the median yield is 15 gpm.

No data are available concerning the hydraulic properties of the middle or upper members.

Freeport Formation.—No data were available.

Illinoian deposits.—No data were available.

Kent end moraine.—Pumping tests were made on 7 wells. The transmissibilities ranged from 100 to 8,000 gpd per ft, although most of them were between 500 and 2,000 gpd per ft. Reported yields on 7 wells ranged from 10 to 30 gpm, and 1 well flowed at the rate of 5 gpm.

Kent ground moraine.—No data available.

Kent outwash.—Pumping tests were made on wells La-130, Mr-701, and Mr-752, from which transmissibilities of 300, 8,000 and 400 gpd per ft were obtained. Recharging boundaries were encountered at wells La-130 and Mr-752 shortly after the test began, which greatly increased the yields. Conversely, a discharging boundary was encountered at well Mr-701 soon after the test began. The yields of 8 other wells ranged from 10 to 20 gpm; the median yield was 11 gpm.

Recent alluvium.—Reported yield of 3 wells are available; well Mr-519 flows at 80 gpm, well Mr-986 yields 5 gpm, and well Mr-1143 yields 20 gpm.

Water use

In 1960, large amounts of ground water were utilized in the Mercer quadrangle by Grove City, Pa., the Cooper-Bessemer Co. (at Grove City), Slippery Rock, Pa., and the Slippery Rock State Teachers College. Small amounts were used for domestic and stock-watering purposes.

The inventory of wells in the quadrangle provides a sufficiently representative sample to permit a rough estimate of the relative importance of the several aquifers as sources of ground-water supply. The following table shows the percentage of total wells inventoried that tap each aquifer. Unconsolidated rocks and the Homewood Formation are the sources of water for about half of the wells.

Aquifer	*Percent of wells*
Recent alluvium	1.5
Kent ground moraine	2.3
Kent end moraine	11.9
Kent outwash	9.7
Kittanning Formation, middle member	1.5
Kittanning Formation, lower member	6.3
Vanport Limestone	2.3
Clarion Formation	9.4
Homewood Formation	23.9
Mercer Formation	3.7
Connoquenessing Formation, upper member	6.4
Connoquenessing Formation, middle member	0.4
Connoquenessing Formation, lower member	2.3
Connoquenessing Formation, undifferentiated	3.8
Burgoon Sandstone	1.4
Hempfield Shale	0.4
Shenango Formation	0.1
Unidentified	12.7
Total	100.00

GEOCHEMISTRY OF THE GROUND WATER

LABORATORY ANALYSES

Chemical analyses of water from 72 wells in the Mercer quadrangle were made by the U. S. Geological Survey. They are tabulated in Table

Well	Dissolved solids (ppm)	Aquifer
1 = Bt-44	689	Unknown
2 = Bt-65	231	Do.
3 = Lo-182	285	Do
4 = Lo-663	284	Do.
5 = Mr-517	345	Do
6 = Mr-538	176	Do
7 = Mr-774	237	Do
8 = Mr-807	237	Do
9 = La Co Brine well	63,200	Berea Sandstone
10 = Bt Co Brine well	22,600	Cussewago Sandstone
11 = Sea water	34,482	

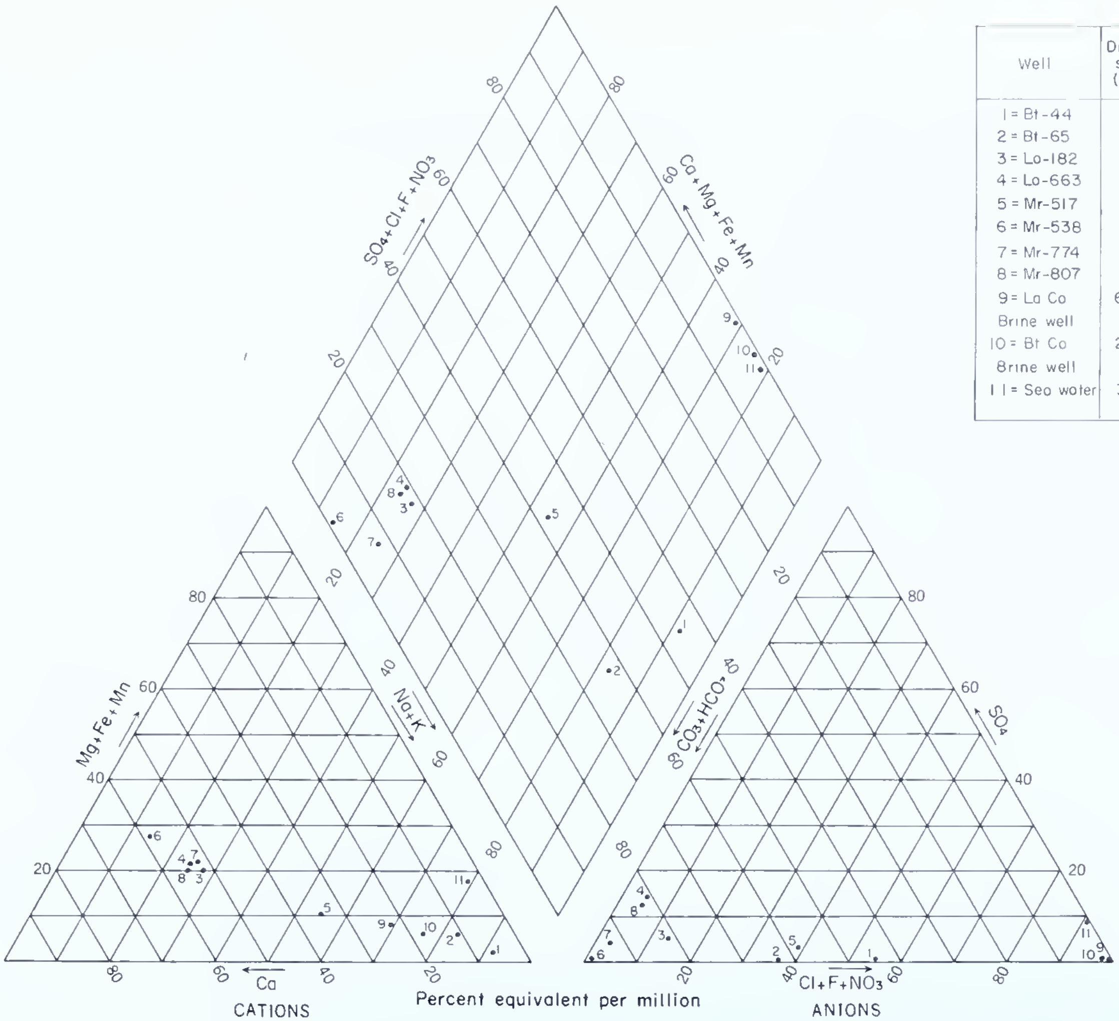


Figure 17. Graph showing chemical analyses of water from abandoned oil or gas wells, the Berea and Cussewago Sandstones, and sea water.

4. The samples analyzed include 14 from glacial or recent deposits, 4 from the Kittanning Formation, 1 from the Vanport Limestone, 6 from the Clarion Formation, 16 from the Homewood Formation, 3 from the Mercer Formation, 13 from the Connoquenessing Formation, 3 from formations of Mississippian age, and 12 from wells in which the aquifer was unknown.

The dissolved-solids content of the samples ranged from 69 to 1,370 ppm (parts per million); in more than 70 percent of the samples, however, it ranged from 100 to 300 ppm. The samples having both the lowest and the highest dissolved-solids content were obtained from wells producing from glacial deposits. The most dilute sample came from a shallow dug well Mr-28 and is believed to consist of water derived from rainfall in the immediate vicinity. The most concentrated sample was obtained from well Mr-706 in a deep buried valley. It is high in sodium (480 ppm) and chloride (620 ppm) and probably reflects discharge into the glacial deposits from a deeply buried bedrock aquifer.

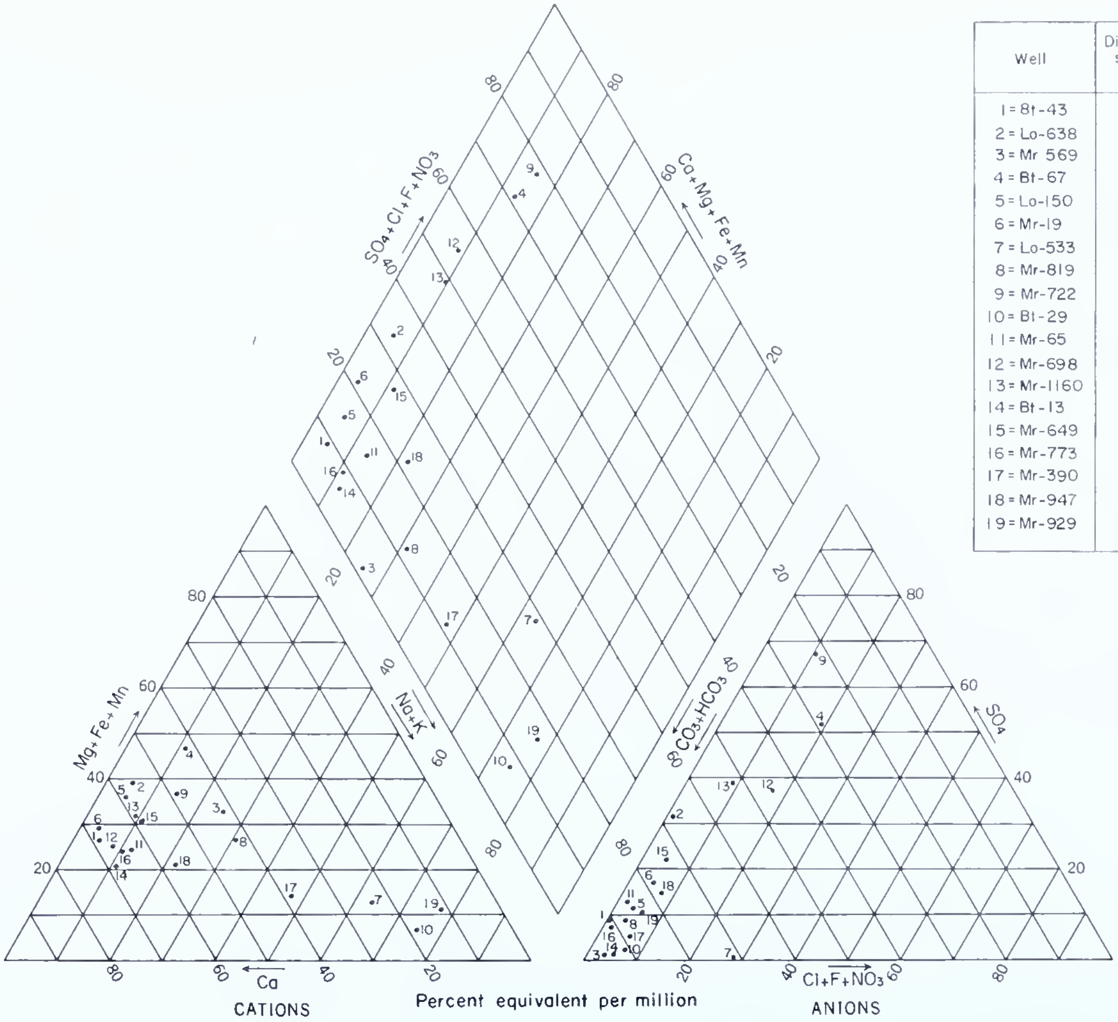
Of 14 other wells whose water contains more than 300 ppm dissolved solids, 3 contain larger-than-average amounts of sodium (23 ppm) and chloride (19 ppm), and the remainder have larger than average concentrations of sulfate (57 ppm) and, usually, of iron. The occurrence of sodium and chloride in the ground water of most sedimentary rocks is part of the normal geochemical cycle and is discussed below. Sulfate and iron may be considered as a special part of the cycle, peculiar to rocks of this type; they are discussed later, in a separate section.

Geochemical Cycle.—The chemical analyses have been plotted in Figures 17-21. These figures were prepared by plotting the percent epm (equivalents per million) of the cations and anions separately in the small triangles in the lower part of each figure. The cation and anion plots were then extrapolated to the diamond-shape field to form a single point representing the composition of the dissolved material of that sample.

The points in Figure 17 represent the analyses of water flowing from some of the abandoned oil and gas wells in the Mercer quadrangle, plus one analysis of sea water and two of Mississippian brines from Butler and Lawrence Counties in areas adjacent to the Mercer quadrangle. These last three waters (points 9, 10, 11) are natural solutions, chiefly of sodium and chloride ions, that are included for convenient reference.

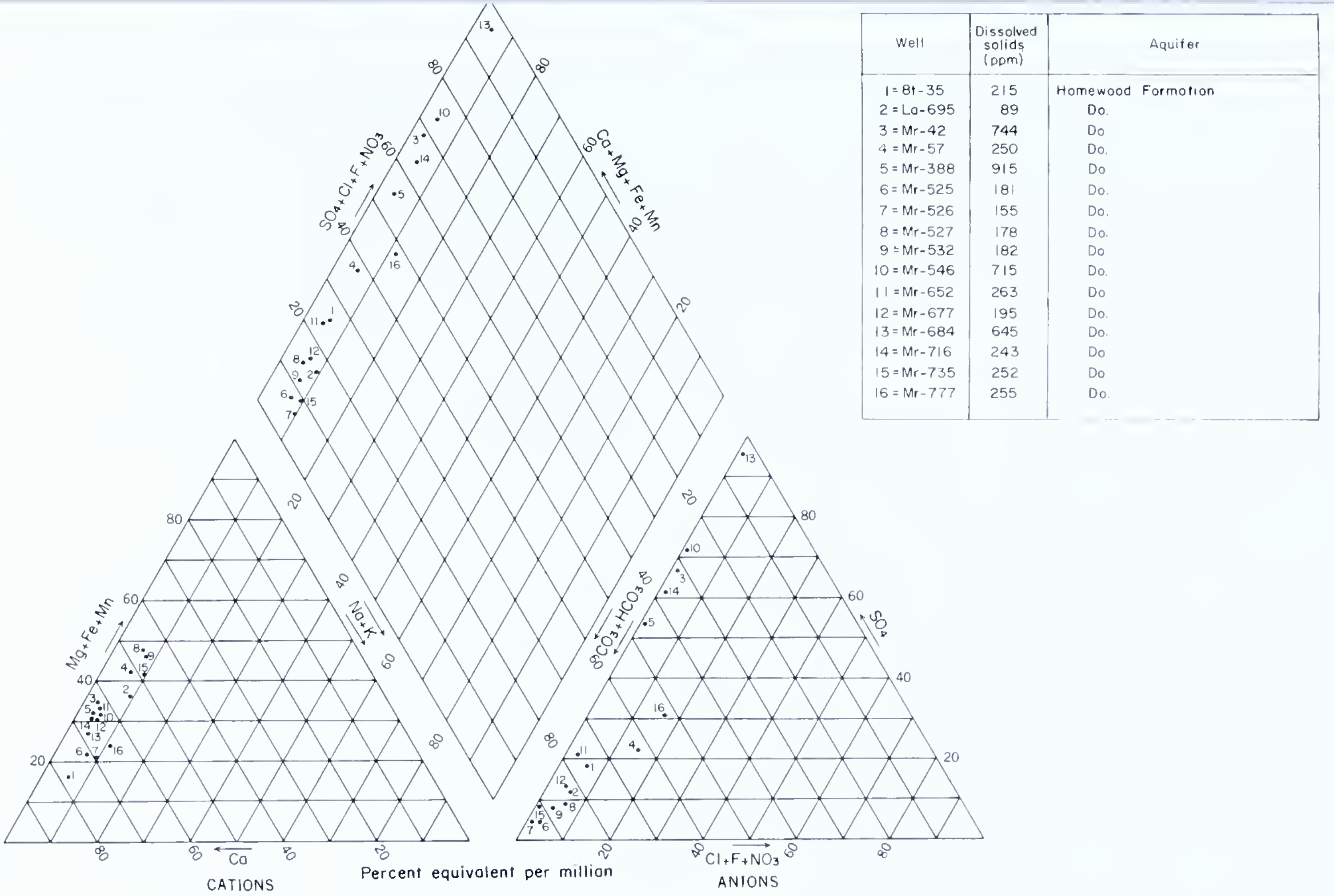
All of these abandoned wells are partially plugged, so that it is not possible to determine the source of the water. Despite the lack of data on their source, some of the samples do furnish worthwhile information.

The samples from wells Bt-44, Bt-65, and Mr-517 are considerably different from most of the others in that more than 50 percent of their cation content is sodium, and 2 of the samples are more sodic than the sea water or the brines. The chloride content ranges from 37 to 55



Well	Dissolved solids (ppm)	Aquifer
1 = Bt-43	245	Mercer Fm
2 = Lo-638	483	Do.
3 = Mr 569	151	Do.
4 = Bt-67	88	Connoquenessing Fm ,upper member
5 = Lo-150	143	Do
6 = Mr-19	144	Do
7 = Lo-533	365	Do
8 = Mr-819	168	Do.
9 = Mr-722	107	Connoquenessing Fm ,middle member
10 = Bt-29	247	Connoquenessing Fm.,lower member
11 = Mr-65	173	Do
12 = Mr-698	131	Do
13 = Mr-1160	123	Do.
14 = Bt-13	182	Connoquenessing Fm. ,undifferentioted
15 = Mr-649	81	Do
16 = Mr-773	198	Do.
17 = Mr-390	240	Burgoon Sondstone
18 = Mr-947	240	Do.
19 = Mr-929	263	Hempfield Shole

Figure 18. Graph shawing chemical analyses of water from the Mercer, Connaquenessing, Burgoan, and Hempfield Farmatians.



Well	Dissolved solids (ppm)	Aquifer
1 = 8t-35	215	Homewood Formation
2 = La-695	89	Do.
3 = Mr-42	744	Do
4 = Mr-57	250	Do.
5 = Mr-388	915	Do
6 = Mr-525	181	Do.
7 = Mr-526	155	Do.
8 = Mr-527	178	Do.
9 = Mr-532	182	Do
10 = Mr-546	715	Do.
11 = Mr-652	263	Do
12 = Mr-677	195	Do.
13 = Mr-684	645	Do.
14 = Mr-716	243	Do
15 = Mr-735	252	Do
16 = Mr-777	255	Do.

Figure 19. Graph showing chemical analyses of water from the Homewood Formation.

percent of the anions (in epm). Despite this briny character, the dissolved-solids content is closer to that of fresh water than to that of the sea water or the oil- and gas-field brines. The dissolved-solids content of the 3 samples ranges from 231 to 689 ppm.

The analyses of water from rocks ranging in age from the Hempfield Shale, of Mississippian age, to the Mercer Formation, of Pennsylvanian age, are plotted in Figure 18. The analyses show a great range in percentage of epms of the various chemical constituents and a notable relation between age and cation composition. Water from the oldest rocks (points 10, 17, and 19) tends to be more sodic than that from the younger rocks (points 1, 2, and 6), although reversals in trend are present (points 3 and 18). Also, the magnesium-calcium ratio of the water decreases as the age of the host rock increases.

The predominant anion in most samples is bicarbonate, although some samples contain large amounts of sulfate; for example, the sulfate content of the water from well Mr-722 is 67.08 percent of the anions (in epm). Chloride exceeds 10 percent of the anions (in epm) only in water from wells Bt-67 (18.18 percent) and La-533 (28.01 percent). The nitrate content of the sample from well Mr-698 is 12.00 percent of the anions (in epm).

Only wells La-533 and La-638 yielded water containing more than 300 ppm dissolved solids. Part of the high dissolved-solids content of the water from well La-533 is due to a relatively large amount of chloride (66 ppm) and part of the high dissolved-solids content of the water from well La-638 is due to a relatively large amount of sulfate (136 ppm).

Analyses of water from the Homewood Formation are plotted in Figure 19. These analyses show much less range in composition than those in previous figures. The sodium content of these samples is less than 10 percent of the cations (in epm) in all samples. Chloride is present in amounts less than 2 percent of the anions (in epm) in most samples and exceeds 5 percent in water from well Mr-57 only; in well Mr-57, it is 15.18 percent. Sulfate reaches its maximum of 95.31 percent of the anions (in epm) in well Mr-684. The water of this well also contained 33 ppm of iron, which was 11.06 percent of the anions (in epm). Nitrate is locally abundant—for example, in well Mr-777 the nitrate content is 13.51 percent of the anions (in epm).

Analyses of water from the Clarion Formation, Vanport Limestone, and Kittanning Formation are plotted in Figure 20. These analyses differ little from those of the Homewood Formation except that they lack the high concentrations of sulfate. The water of well Bt-98 contains an anomalously high chloride concentration (29 ppm).

Analyses of water from the glacial and recent sediments are plotted in Figure 21. This water ranges widely in concentration and composition,

Well	Dissolved solids (ppm)	Aquifer
1 = Lo-712	185	Kittonning Fm , middle member
2 = 8t-98	192	Kittonning Fm., lower member
3 = Lo-493	289	Do.
4 = Lo-677	413	Do
5 = 8t-83	503	Vanport Limestone
6 = 8t-52	230	Clarion Formation
7 = Lo-107	275	Do
8 = Mr-51	243	Do.
9 = Mr-545	193	Do
10 = Mr-805	182	Do.
11 = 5-359	209	Do
12 = 8t-25	285	Do.

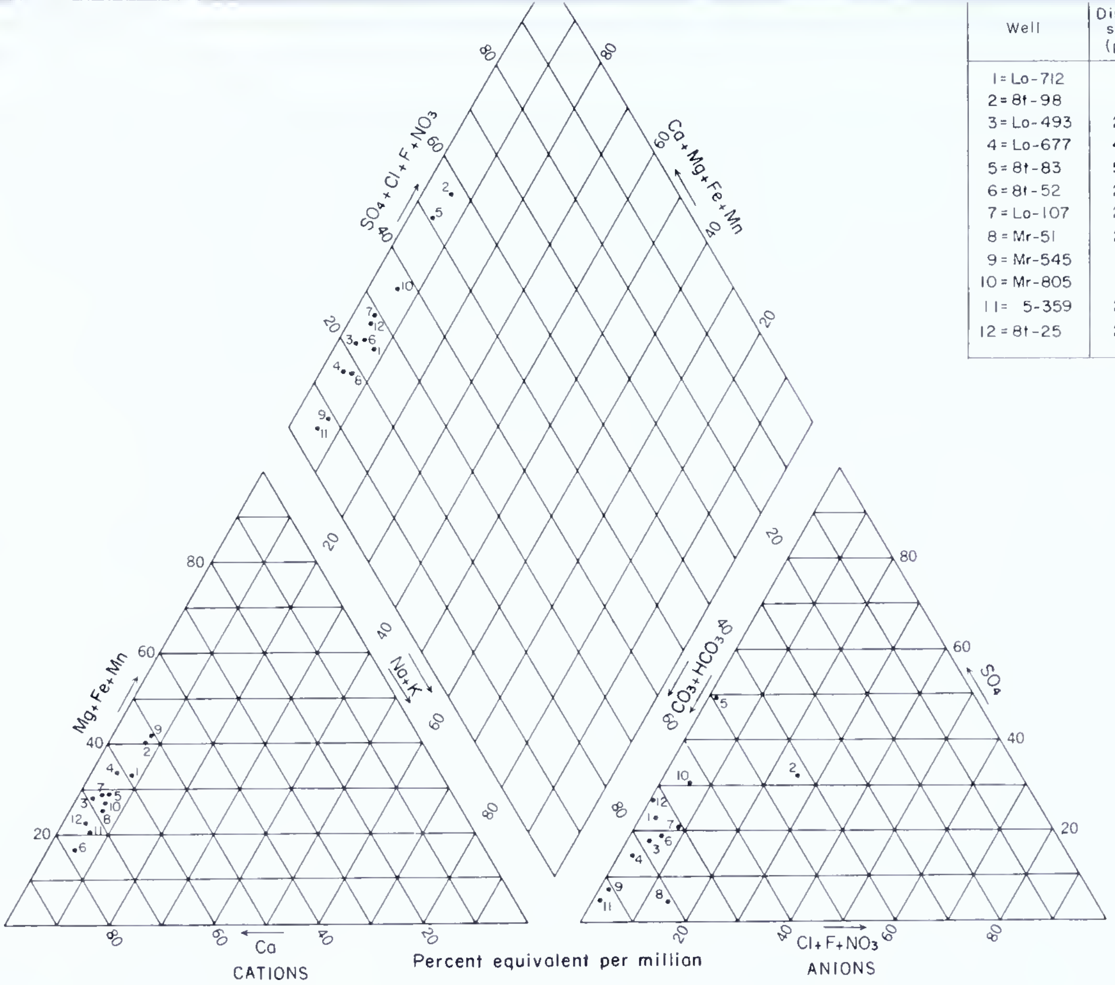
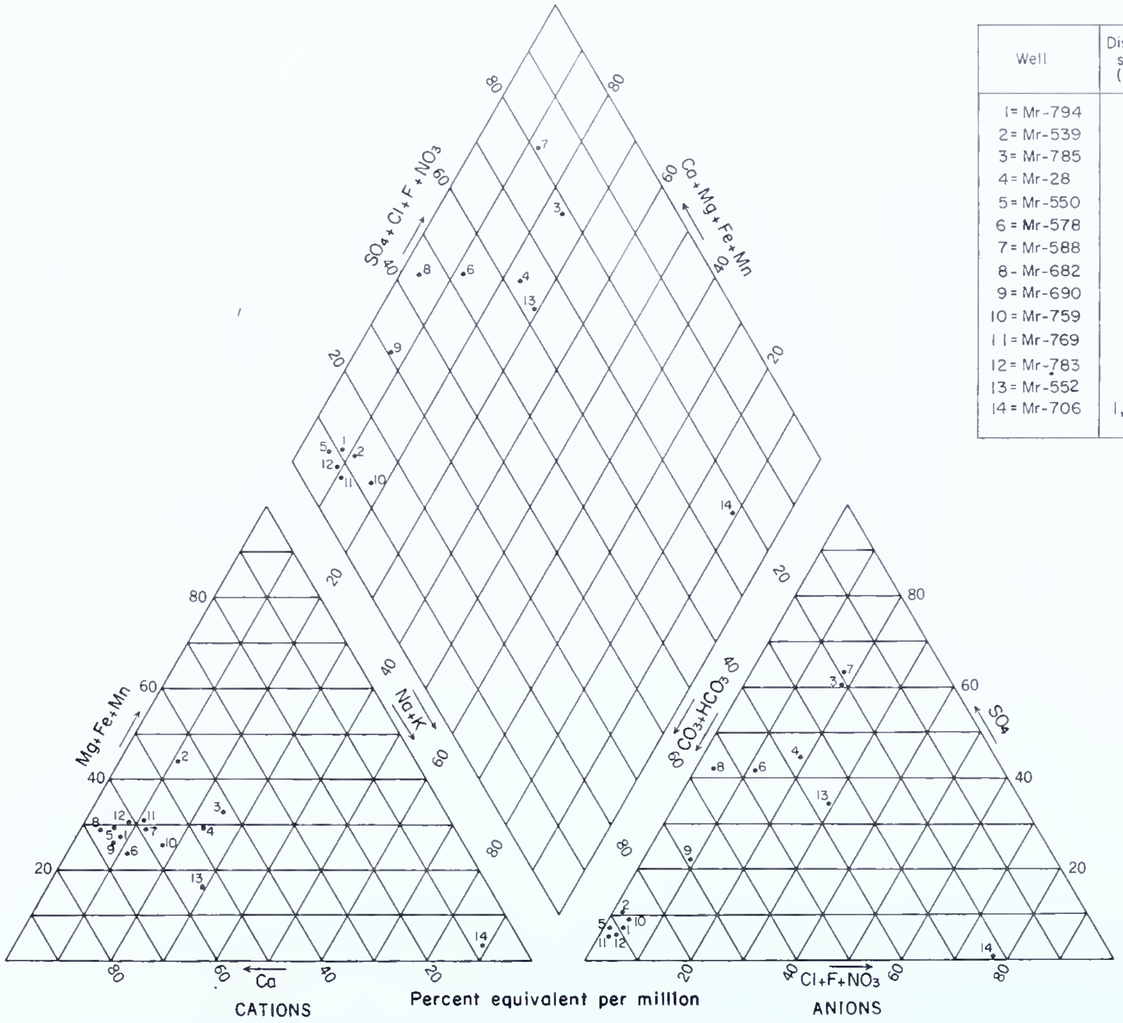


Figure 20. Graph showing chemical analyses of water from the Kittanning Formation, Vanport Limestone, and Clarion Formation.



Well	Dissolved solids (ppm)	Aquifer
1 = Mr-794	245	Recent alluvium
2 = Mr-539	155	Kent ground moraine
3 = Mr-785	85	Do.
4 = Mr-28	69	Kent end moraine
5 = Mr-550	188	Do
6 = Mr-578	340	Do.
7 = Mr-588	93	Do
8 - Mr-682	313	Do
9 = Mr-690	106	Do.
10 = Mr-759	254	Do.
11 = Mr-769	200	Do.
12 = Mr-783	118	Do
13 = Mr-552	198	Kent outwash
14 = Mr-706	1,370	Do

Figure 21. Graph showing chemical analyses of water from unconsolidated deposits.

reflecting the fact that over much of the quadrangle these sediments contain water that comes from the underlying bedrock.

Above-average nitrate concentrations for the area (2.2 ppm) are present in wells Mr-28, Mr-552, Mr-578, Mr-588, Mr-690, and Mr-785. The nitrate content ranges from 1.94 to 18.36 percent of the anions (epm).

To obtain some understanding of how this water acquired its chemical character, it is necessary to know something of the chemical changes that take place in water as it passes through the subsurface part of the hydrological cycle. Precepitation, at it falls on the earth's surface, contains little dissolved material other than a small amount of oxygen, oxides of nitrogen, and carbon dioxide, though within the soil zone the water acquires additional carbon dioxide. The dissolved carbon dioxide enables the water to dissolve calcium and magnesium carbonates (plus small amounts of other minerals) and become, typically, a calcium and magnesium bicarbonate water.

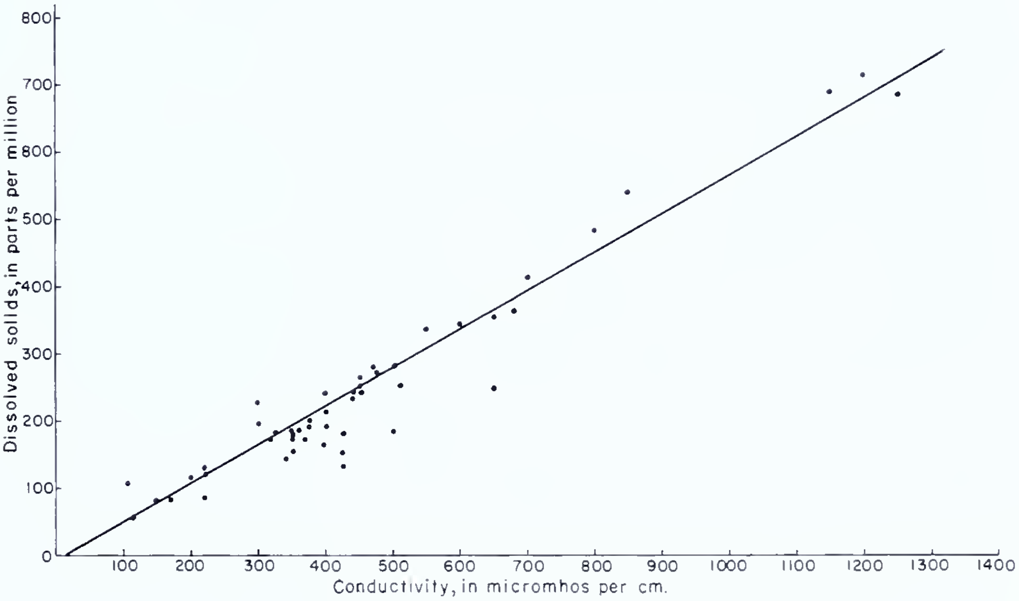


Figure 22. Graph showing relation of field conductivity to dissolved solids.

As the water percolates downward, the dissolved solids continue to increase. However, as noted earlier, the dissolved solids do not exceed 300 ppm except where sizable amounts of chloride or sulfate are present.

As the meteoric water moves downward it displaces (flushes) the water present in the rocks at the time of their deposition. Because the water originally present probably was sea water, rocks in which the flushing is incomplete can be expected to contain water resembling sea water. For example, some of the abandoned oil and gas wells shown in Figure 17, such as wells Bt-44, Bt-65 and Mr-517, contain brackish water.

The chloride is readily removed by circulating ground water, but the sodium is more difficult to remove because much of it is adsorbed on the clay in the rocks. The sodium, therefore, persists longer than the chloride. Ion exchange between the clay and the constituents of the flushing water is believed to be the cause of the high sodium content of the samples from wells Bt-44 and Bt-65.

If the surface of the Mercer quadrangle were a level plain underlain by horizontal strata of uniform permeability and thickness, at some elevation above points of discharge there would be a perfect correlation between the composition of the dissolved solids in the ground water and both the age of the different strata and their depth below the surface. However, this is not true, and a less-than-perfect correlation exists because the composition of the dissolved solids is influenced strongly by the pattern of circulation described in the section on hydrology and by the presence of fractures that make some areas much more permeable than others. The pattern of circulation results in a deeper flushing of the rocks beneath the hills than beneath the valleys, where the general movement of water is upward. The composition of the dissolved solids in water from wells Bt-29 and Mr-533 reflect this upward movement of the water.

The composition of the dissolved solids may be affected also by heavy pumping in an area. For example, although both wells Mr-390 and Mr-947 penetrate the Burgoon Sandstone, well Mr-390 (an isolated well near the southern edge of Grove City) yields water more characteristic of Mississippian rocks than does well Mr-947, which is in the heavily pumped Grove City-Cooper-Bessemer well field. Presumably, the heavy pumping has resulted in a large amount of flushing so that the water from well Mr-947 is less sodic than that from well Mr-390. Both wells have the same dissolved-solids content of 240 ppm.

Occurrence of iron and sulfate.—Determinations of iron content were made on 69 samples. The iron content ranged from nondetectable concentrations in two samples from the Connoquenessing Formation (wells Bt-13 and Mr-19) to 33 ppm in a sample from the Homewood Formation (well Mr-684). About half the samples contained less than 1 ppm iron and over three-fourths contained less than 3 ppm iron.

The 15 samples that contained 3 ppm or more of iron were taken from wells penetrating the Connoquenessing, Mercer, Homewood, and Kittanning Formations, in widely separated parts of the quadrangle.

Iron in the water is probably derived chiefly from the oxidation of pyrite or marcasite, which occurs either in masses interbedded with overlying coal or finely disseminated in the strata overlying the coal. Newhouse (1927, p. 73) states that iron sulfide occurs more commonly as marcasite in coal and as pyrite in other sedimentary rocks. The amount of iron in the well water may vary with time or pumping rate and is due to such factors as the Eh, pH, carbon dioxide, and sulfur content of the solution. Eh (a measurement of the oxidizing or reducing potential of the solution) is especially important, and Hem (1960, p. 71) reports that an increase of about 0.02 volts at constant pH may result in a change in the solubility of ferrous iron from 0.01 ppm to 100 ppm. In aerated water having an Eh of about 0.40 volts, the iron will be deposited as the oxide or hydroxide. The solubility of the iron varies inversely with the pH, which is a measurement of the acidity of the solution (acidity decreases as the pH increases). Carbon dioxide in solution acts to control iron solubility by its effect on the pH and by the formation of chemical complexes with the iron. Sulfur, chiefly in its reduced form, effects the iron solubility by removing the iron from the solution as the sulfide.

The problem is further complicated by the fact that a well may receive water from zones not in chemical equilibrium with one another. If this water is then removed from the well before equilibrium is established, unusual effects—such as the presence of iron in solution with free sulfide ions—may be noted. (See Hem, 1960, p. 67.)

Determinations of sulfate were made on 72 samples. The sulfate ranged from nondetectable concentrations in three abandoned oil or gas wells having unidentified aquifers (wells Bt-44, Bt-56, and Mr-538) to 451 ppm in the Homewood Formation (well Mr-684). About half the samples contained less than 25 ppm sulfate, and more than three-fourths contained less than 50 ppm sulfate. The sulfate content was more than 100 ppm in 11 samples, most of which were from the Homewood Formation.

Like iron, the sulfate is derived chiefly from the oxidation of pyrite, although Moore (1940, p. 49) points out that organic sulfur may run as high as 3 percent in some coals. Because of the complex environment in which the iron and sulfate ions exist in nature, a high concentration of one in a solution would not necessarily be accompanied by a high concentration of the other.

Place in the geochemical cycle.—Iron sulfide is attacked by oxygenated water, as follows:

$$FeS_2 + H_2O + 3\frac{1}{2}O_2 \rightarrow Fe^{+2} + 2H^{+1} + 2SO_4^{-2}$$

The increased acidity resulting from this reaction facilitates the solution of other minerals present in the rocks. If no further oxidation occurs, the iron will eventually be flushed from the system. However, if the iron undergoes further oxidation—to ferric iron—it will generally be precipitated and form a coating of oxide on the mineral grains of the rock, helping to cement the grains together and acting to reduce the porosity and permeability of the rock. A return to reducing conditions may redissolve the iron; but, more likely, as Hem (1960, p. 72) points out, the iron will remain as a coating on the grains.

The sulfate ion may be flushed out, it may be precipitated—as when it reacts with calcium to form gypsum—or it may be attacked by sulfate-reducing bacteria in the deeper parts of the system and returned to sulfide. As the sulfide, it may be liberated from the system as gaseous hydrogen sulfide or it may be precipitated, perhaps as iron sulfide.

The quality of ground water in the bedrock is related to the present environment and circulation history of the water and to the environment in which the sediments were deposited. Quiet water, having restricted circulation and a deficiency in oxygen, is one of the requisites for the formation of iron sulfide. In such an environment, decaying vegetation forms methane, which, with the aid of anaerobic bacteria, reacts with the sulfate present to reduce it to sulfide. If the water is shallow enough and the supply of sediments small, a peat bog may develop, and the iron sulfide will be found in the peat, or in the resultant coal.

The growth of coal-forming plants is inhibited in deep water, and the sediments deposited there, under reducing conditions, contain disseminated iron sulfides. Such sediments are generally dark gray to black, owing to the presence of sulfides and finely macerated organic matter.

Sediments deposited in well-oxygenated water will be free of iron sulfides, and the ground water that they contain will be correspondingly low in these constituents except where it has been contaminated from other sources.

The influence of the environment of deposition is shown best in the Mercer quadrangle by the Clarion Formation. The oxidizing conditions that prevailed in the southeastern part of the area, where fluvial sands of the Clarion were laid down, are responsible for water low in iron, such as that from station 31. Northward and westward, as in the vicinity of well Mr-684, sulfides deposited under the reducing conditions present at the time the Brookville coal was forming are the source of the iron in the water in the underlying Homewood Formation. Still farther northwestward (as in the vicinity of well Mr-716) where the reducing conditions extended to the Clarion sediments, overlying the Brookville coal, the iron contamination extends to the water in the Clarion Formation.

Effect on water use.—More than 0.3 ppm of iron, 0.05 ppm manganese, or 250 ppm sulfate in drinking water is considered undesirable by the U. S. Public Health Service (1961). In the Mercer quadrangle, 15 of the 68 samples analyzed for iron and manganese and 68 of the 72 samples analyzed for sulfate met these standards.

Nitrate.—The nitrate content of the water in the Mercer quadrangle ranges from nondetectable concentrations to 35 ppm, although more than three-fourths of the samples contain less than 1 ppm. Of the 17 samples having more than 1 ppm, 11 were from unconsolidated rocks or from bedrock that is overlain directly by unconsolidated rocks. The presence of nitrate in above-average amounts in areas that are under cultivation suggests strongly that the nitrate may be derived from fertilizer that has been added to the fields. As the nitrate ion is stable and forms soluble compounds with most cations, it is not apt to be removed from solution except by nitrogen fixation by plants. Any amount beyond that needed immediately by the plants, therefore, would be readily carried downward, by infiltrating precipitation, to the ground water. The nitrate might also be expected to continue downward to the deeper aquifers.

FIELD ANALYSES

In addition to the samples that were analyzed in the laboratory, 407 samples from 362 wells were analyzed in the field. Determinations of pH, hardness, and conductivity were made on most samples. A few of the wells were resampled at a later time, and one or more of these properties were remeasured. The field analyses are summarized in the table on page 84.

Conductivity.—The relation of the field measurement of conductivity (C) to the dissolved solids (S) determined in the laboratory (see Fig. 22) was found, by the least squares method, to be

$$S = 0.5734\,C - 9.15$$

The closeness of the relationship is indicated by the coefficient of correlation, which is 0.979.

Because of the close correlation between field conductivity measurements and the dissolved solids of the samples, the conductivities of the water can be used to estimate the dissolved solids, thus, effectively extending knowledge of the dissolved solids of the water of the Mercer quadrangle from 72 wells to several hundred wells.

In the discussion of the laboratory analyses, it was noted that concentrations of dissolved solids greater than 300 ppm were due, in part, to excessive amounts of either chloride or sulfate. Also, the chloride concentrations were observed to decrease directly as the age of the bedrock. Except for the sample from well La-533, which came from the Connoquenessing Formation, the large concentrations of chloride were shown to be in water from rocks of Mississippian age or older. In other words, the high dissolved solids (and high conductivity) of a sample of water from a Pennsylvanian formation is probably due to the presence of large amounts of sulfate.

Hardness.—An increase in anion concentration is accompanied, of course, by an increase in the cation concentration. Where chlorides are prom-

Summary of field analyses of water samples (see Table 5)

	pH		Hardness			Specific Conductance		
				Grains per gallon[1]			*Micromhos at 25°C.*	
	Number of samples	*Range*	*Number of samples*	*Range*	*Average*	*Number of samples*	*Range*	*Average*
Recent alluvium	6	5.4-7-3	6	5-14	10	5	190- 440	320
Kent ground moraine	10	5.5-8.3	10	3-15	9	10	150- 560	338
Kent end moraine	50	5.3-7.9	49	3-29	10	52	106-1,800	410
Kent outwash	47	5.3-8.1	48	2-22	10	48	60-2,570	467
Kittanning Formation, middle member	3	5.9-7-5	3	6-18	11	3	170- 435	318
Kittanning Formation, lower member	19	5.5-7.4	19	3-22	13	19	120- 725	479
Vanport Limestone	5	6.6-7.6	5	7-16	12	4	190- 530	424
Clarion Formation	25	5.7-7.4	24	6-28	14	27	140-1,150	474
Homewood Formation	102	5.4-7.8	99	4-47	14	100	150-1,400	449
Mercer Formation	13	5.8-7.2	13	3-26	13	13	350- 900	517
Connoquenessing Formation, upper member	33	5.6-7-7	32	3-22	10	34	50-1,200	329
Connoquenessing Formation, middle member	2	5.7-6.6	1		5	1		270
Connoquenessing Formation, lower member	12	5.5-7.6	13	3-11	7	13	130- 450	266
Connoquenessing Formation, undifferentiated	18	5.5-7.8	16	7-21	10	19	100- 580	320
Hempfield Shale	1		1		2	1		450
Unidentified	40	5.5-8.0	41	3-24	12	41	175-1,500	483
Total	385	5.3-8.3	380	2-47	12	390	50-2,570	429

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[1] Grains per gallon may be converted to parts per million by multiplying grains per gallon by 17.12.

inent, so are the alkali metals. Moreover, an increase in the sulfate content of the water results in a corresponding increase in calcium and magnesium. The concentrations of these alkaline-earth metals may be estimated from the hardness of the water. The relation of the field hardness value (H) to the combined concentrations of calcium and magnesium (CM) (see Fig. 23) was found, by the least squares method, to be

$$CM = 5.90\,H + 0.03$$

The coefficient of correlation was 0.919.

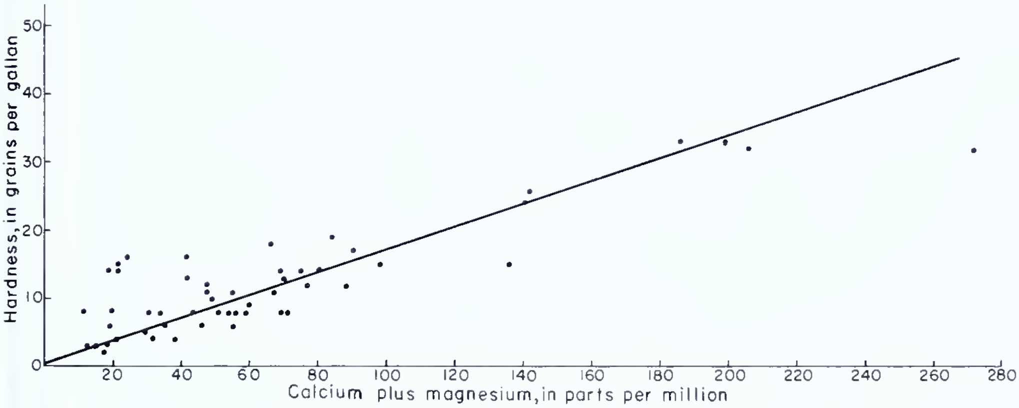

Figure 23. Graph showing relation of field hardness to calcium plus magnesium.

pH.—Field measurements of pH ranged from 5.3 to 8.3. About half the samples had a pH between 7.0 and 7.6, 45 percent had a pH less than 7.0, and only 5 percent had a pH of 7.7 or more. Similarly, the laboratory measurements showed the pH of about half the samples to be between 7.0 and 7.6. In contrast to the field measurements, however, the pH of the remaining samples was about equally distributed above and below this 7.0-7.6 range. This difference between field and laboratory measurements of pH reflects the equilibrium established between the several constituents in solution. If this equilibrium is disturbed—as by the escape of carbon dioxide from the water because of the relief of confining pressure as the water is pumped from the well, or by a change in the water's temperature—the pH will change also.

Areal pattern of analyses.—The areal distribution of all field conductivity measurements of the ground-water are plotted in Figure 24. The data were insufficient to permit correlation of the areal distribution with the individual aquifers, but they show a crude relationship to the drainage pattern in the basins of Neshannock Creek, Slippery Rock Creek, and the northern part of Wolf Creek.

The higher conductivities become more abundant northwestward, and most of them probably are due to the local oxidation and solution of sulfides.

Change of water with time.—Most of the field analyses were made in the fall of 1956, but a second field analysis was made on the water from some of the wells. The second analysis was generally made when a sample was collected for laboratory analysis. The results are included with the other field analyses in Table 5. The resampling in most cases was at one of two times—either the following spring or in the fall, 1 year after the original inventory of the well. Accordingly, the samples are separated into these two categories.

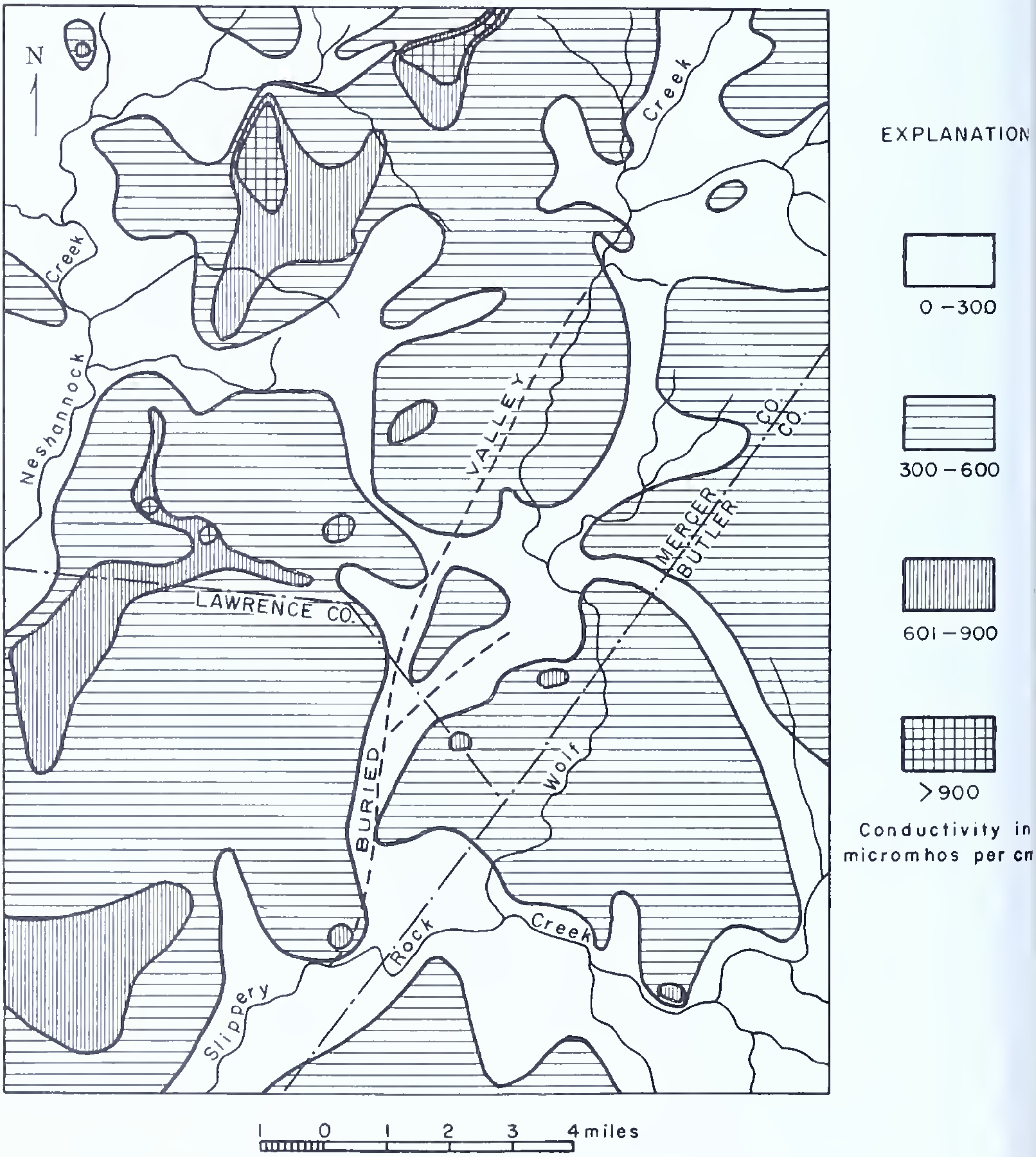

Figure 24. Map showing areal variation in field conductivity measurements of ground water in the Mercer quadrangle.

The fall-to-spring group shows only changes that are within the limits of experimental error of the determinations. By use of Snedecor's F-test[1] a significant change in the conductivity is shown to be present in the fall-to-fall group.

Inspection of the analyses shows that those samples showing a considerable decrease in conductivity are from the Pleistocene rocks. The decrease was probably caused by recharge from precipitation, shortly before the samples were taken.

The cause of the increase in conductivity in other samples is believed to be related to a deficiency in rainfall during the 1957 water-year (October 1 to September 30). The following table shows precipitation in inches, by month, for the 1956 and 1957 water years at the recently established weather station at Slippery Rock, Pa. (See U. S. Department of Commerce, 1955, 1956, 1957.)

Month	*1956*	*1957*
October	3.72	0.90
November	3.58	0.99
December	0.46	2.95
January	1.15	2.07
February	6.02	1.72
March	3.82	1.69
April	5.23	4.83
May	4.80	3.60
June	11.07	3.61
July	9.18	2.25
August	5.26	1.20
September	2.85	3.10
Total	57.14	28.91

If the wells showing an increase in conductivity receive water from several aquifers whose piezometric surfaces stand above land surface, the composition of the dissolved solids will be a function of the amount and character of the water contributed to the well by each aquifer. Furthermore, if the upper aquifer is strongly influenced by local precipitation, the amount of water it contributes to the well will decrease in dry years. On the other hand, the deeper aquifers will be less sensitive to local changes in precipitation and their contribution of water to the well will be more constant. A local drought will, therefore, shift the composition of the water toward that of the deeper aquifers.

CONCLUSIONS

Geological.—The consolidated rocks of the Mercer quadrangle range in age from Mississippian to Pennsylvanian. They were deposited on or in the vicinity of deltas which grew northward and westward.

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[1] $$F = \frac{\text{variance beween falls}}{\text{Total variance} - \text{variance between falls} - \text{variance between sample pairs}}$$

$$= \frac{133.956}{16.772} = 7.99.$$ which exceeds the theoretical F of 6.04 for 1 and 17 degrees of freedom at the 0.975 probability level.

During Early Pennsylvanian time, the area was uplifted. The ensuing erosion removed Late Mississippian deposits—so that when the area was submerged, sediments were once more carried into the area from the south and southeast and were deposited on rocks of Early Mississippian age.

As a result of deposition in deltaic environments, sharp lateral and vertical changes in the lithology of these rocks are common.

Sand was deposited most abundantly in the western part of the area and mud was deposited most abundantly in the eastern part. During lithification the mud compacted more than the sand, so that gentle folds developed.

Mature dissection in pre-Pleistocene time produced deep valleys whose orientation is parallel to the strike of joints in the area. These valleys are now partly or completely filled with glacial materials. The form of the valleys has been delineated from well data.

Hydrologic.—The mature dissection of the bedrock divided the Mercer quadrangle into a number of "hydrologic islands," each with its own pattern of ground-water circulation. Precipitation enters the upper part of the "islands" and is discharged through the outcrop areas of the aquifers along the perimeter of the "islands."

Pores and fractures in the rocks are important as avenues of movement of the water. Cementation is irregular and has caused some aquifers to yield from only a few discrete zones.

Determinations of transmissibility, made from pumping tests of 37 wells, range from about 100 gpd per ft. to 400,000 gpd per ft. The highest transmissibilities were obtained from the Burgoon, Connoquenessing, and Clarion Formations.

The complex facies and fracture patterns combine to impose boundary conditions that limit the accuracy of the determinations of transmissibility, because the cone of influence of a pumping well may intersect zones of greater or lesser permeability as pumping progresses. This lack of homogeneity is inconsistent with conditions assumed in the method for computing transmissibility.

Geochemical.—Most of the ground water is of the calcium and magnesium bicarbonate type, as is normally developed in near-surface aquifers. This water is slowly flushing the deeper aquifers of the saline water originally present. The flushing has proceeded farthest in areas of high permeability and where increased movement of water has been induced by large amounts of pumping, as in the Grove City area.

The oxidation of iron sulfides associated with coal deposits has produced water high in iron and sulfate. The occurrence of iron sulfides in the sediments is controlled by conditions in their basin of deposition.

The presence of iron and sulfate in the ground water today is related to the paleogeography and the pattern of circulation of the ground water.

Because conductivity is shown to bear a close correlation to dissolved solids and, similarly, hardness is closely correlated to calcium and magnesium combined, the measurement of conductivity and hardness in the field furnish an easy and inexpensive method of partially appraising the chemical character of the water. The areal pattern of conductivity shows a crude relationship to the surface drainage. Measurement of the conductivity at selected wells 1 year after the initial sampling showed a change in water quality that appeared to be related to a deficiency in rainfall during the intervening time.

REFERENCES

Ashley, G. H. (1926), *Punxsutawney quadrangle*, Pennsylvania Geol. Survey, 4th ser., Atlas 65, 145 p.

——— (1945), *The Pittsburgh-Pottsville boundary,* Jour. Geology, v. 53, p. 374-389.

Bennett, G. D., and Patten, E. P., Jr. (1960), *Borehole geophysical methods for analyzing specific capacity of multiaquifer wells,* U. S. Geol. Survey Water-Supply Paper 1536-A, 25 p.

Butts, Charles (1904), *Description of the Kittanning quadrangle (Pennsylvania),* U. S. Geol. Survey Geol. Atlas, Folio 115.

———(1908), *Pre-Pennsylvanian stratigraphy, in* Report of Topographic and Geologic Survey Commission of Pennsylvania, 1906-1908, p. 190-204.

Caster, K. E. (1934), *The stratigraphy and paleontology of northwestern Pennsylvania,* pt. 1, *stratigraphy,* Bull. of Am. Paleontology, v. 21, no. 71, 185 p.

Chamberlin, T. C. (1883), *Preliminary paper on the terminal moraine of the second epoch,* U. S. Geological Survey 3rd Ann. Rept., p. 330-352.

Chance, H. M. (1879), *The geology of Butler County and the area along the Beaver and Shenango Rivers in Beaver, Lawrence, and Mercer Counties,* Pennsylvania Second Geol. Survey, Rept. V, 248 p.

DeWolf, F. W. (1929), *New Castle quadrangle,* Pennsylvania Geol. Survey, 4th ser., Atlas 5, 238 p.

Dickey, P. A., and others (1943), *Oil and gas geology of the Oil City quadrangle, Pennsylvania,* Pennsylvania Geol. Survey, 4th ser., Bull. M-25, 201 p.

Fenneman, N. M. (1938), *Physiography of Eastern United States,* New York, McGraw-Hill Book Co., 714 p.

Ferm, J. C., and Williams, E. G. (1960), *Stratigraphic variations in some Allegheny rocks of western Pennsylvania,* Am. Assoc. Petroleum Geologists Bull., v. 44, p. 495-497.

Fettke, C. R. (1954), *Structure-contour maps of the plateau region of north-central and western Pennsylvania,* Pennsylvania Geol. Survey, 4th ser., Bull. G-27, 27 p.

——— (1961), *Well-sample descriptions in northwestern Pennsylvania and adjacent states,* Pennsylvania Geol. Survey, 4th ser., Bull. M-40, 691 p.

Fuller, J. O. (1955), *Source of Sharon conglomerate of northeastern Ohio,* Geol. Soc. America Bull., v. 66, p. 159-176.

Graeber, C. K., and Foose, R. M. (1942), *Brookville quadrangle,* Pennsylvania Geol. Survey, 4th ser., Atlas 54, 136 p.

Hem, J. D. (1959), *Study and interpretation of the chemical characteristics of natural water,* U. S. Geol. Survey Water-Supply Paper 1473, 269 p.

——— (1960), *Some chemical relationships among sulfur species and dissolved ferrous iron,* U. S. Geol. Survey Water-Supply Paper 1459-C, p. 57-73.

Hendrix, T. E. (1957), *A petrologic study of two Lower Pennsylvanian sandstones from western Pennsylvania,* unpublished masters thesis, Univ. of Wisconsin, 77 p.

Hubbard, M. K. (1940), *The theory of ground water motion,* Jour. Geology, v. 48, p. 785-944.

Leggette, R. M. (1936), *Ground water in northeastern Pennsylvania,* Pennsylvania Geol. Survey, 4th ser., Bull. W-3, 215 p.

Lesley, J. P. (1877), *Preface to HHH, in* F. and W. G. Platt, *Report of progress in the Cambria and Somerset district of the bituminous coal fields of western Pennsylvania,* pt. II, *Somerset,* Pennsylvania Second Geol. Survey, Rept. HHH, 348 p.

Leverett, Frank (1902), *Glacial formations and drainage features of the Erie and Ohio basins,* U. S. Geol. Survey Mon. 41, 802 p.

——— (1934), *Glacial deposits outside of the terminal moraine in Pennsylvania,* Pennsylvania Geol. Survey, 4th ser., Bull. G-7, 123 p.

Moore, E. S. (1940), *Coal,* New York, John Wiley and Sons, Inc., 473 p.

Newhouse, W. H. (1927), *Some forms of iron sulfide occurring in coal and other sedimentary rocks,* Jour. Geology, v. 35, p. 73-83.

Patten, E. P., Jr. and Bennett, G. D. (1962), *Methods of flow measurement in well bores,* U. S. Geol. Survey Water-Supply Paper 1544-C, 28 p.

Piper, A. M. (1933), *Ground water in southwestern Pennsylvania,* Pennsylvania Geol. Survey, 4th ser., Bull. W-1, 406 p.

Preston, F. W. (1950), *Glacial foreland of northwestern Pennsylvania,* Guidebook, Field Conference of Pennsylvania Geologists, 16th Ann. Meeting, Pittsburgh, Pennsylvania, p. 11-36.

Rankama, K., and Sahama, T. G. (1950), *Geochemistry,* Chicago, The University of Chicago Press, 912 p.

Richardson, G. B. (1936), *Geology and mineral resources of the Butler and Zelienople quadrangles, Pennsylvania,* U. S. Geol. Survey Bull. 873, 93 p.

——— (1938), *Structure contour maps of the Pittsburgh-Huntington basin,* Geol. Soc. America Bull., v. 39, p. 543-554.

Rogers, H. D. (1858), *The geology of Pennsylvania, v. 2,* Philadelphia, J. B. Lippincott and Co., 1045 p.

Shepps, V. C., and others (1959), *Glacial geology of northwestern Pennsylvania,* Pennsylvania Geol. Survey, 4th ser., Bull. G-32, 59 p.

Sherrill, R. E., and Matteson, L. S. (1939), *Geology of the oil and gas fields of the Hilliards quadrangle (Advance report),* Pennsylvania Geol. Survey, 4th ser., Bull. 122, 25 p.

——— (1941), *Oil and gas geology of the Franklin quadrangle,* Pennsylvania Geol. Survey, 4th ser., Bull. M-24, 71 p.

Sitler, R. F. (1957), *Glacial geology of a part of western Pennsylvania,* unpublished Ph.D. thesis, Univ. of Illinois, Urbana, Illinois.

Theis, C. V. (1935), *The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground water storage*, Am. Geophys. Union Trans., pt. 2, p. 519-524.

U. S. Department of Commerce (1955), *Climatological data, Pennsylvania.*

———— (1956), *Climatological data, Pennsylvania.*

———— (1957), *Climatological data, Pennsylvania.*

U. S. Public Health Service (1961), *Report of the advisory committee on revision of the U. S. Public Health Service 1946 drinking water standards*, Am. Water Works Assoc. Jour., v. 53, no. 8, p. 935-945.

Walton, W. C. (1953), *The hydraulic properties of a dolomite aquifer underlying the village of Ada, Ohio,* Tech. Rept. 1, Ohio Div. Water, Columbus, Ohio, 31 p.

Weller, J. M. (1960), *Stratigraphic principles and practice,* New York, Harper and Brothers, 725 p.

Weller, J. M., and others (1948), *Correlation of the Mississippian formations of North America,* Geol. Soc. America Bull., v. 59, p. 91-196.

Wenzel, L. K. (1942), *Methods for determining permeability of water-bearing materials,* U. S. Geol. Survey Water-Supply Paper 887, 192 p.

White, I. C. (1878), *Report of progress in the Beaver River district of the bituminous coal-fields of western Pennsylvania,* Pennsylvania Second Geol. Survey, Rept. Q, 337 p.

———— (1879), *The geology of Lawrence County,* Pennsylvania Second Geol. Survey Rept. QQ, 336 p.

———— (1880), *The geology of Mercer County,* Pennsylvania Second Geol. Survey Rept. QQQ, 233 p.

———— (1881), *The geology of Erie and Crawford Counties,* Pennsylvania Second Geol. Survey Rept. QQQQ, 406 p.

Williams, E. G. (1959), *Aspects of the paleogeography of the coal measures of western Pennsylvania,* Mineral Industries, v. 28, no. 9, p. 1, 3-5.

———— (1960), *Marine and fresh water fossiliferous beds in the Pottsville and Allegheny Groups of western Pennsylvania,* Jour. Paleontology, v. 34, p. 908-922.

Williams, H. S. (1891), *Correlation papers; Devonian and carboniferous,* U. S. Geol. Survey Bull. 80, p. 1-279.

APPENDIX

Tables 3 to 6

Table 3.—Record of wells

Method of construction: Drl, drilled; Drn, driven.
Total depth: r, reported.
Depth to bottom of casing: r, reported.
Aquifer name: Qal, Recent alluvium; Qgm, Kent ground moraine; Qem, Kent end moraine; Qo, Kent outwash; Pku, Kittanning Formation, upper member; Pkm, Kittanning Formation, middle member; Pkl, Kittanning Formation, lower member; Pv, Vanport Limestone; Pcn, Clarion Formation; Ph, Homewood Formation; Pm, Mercer Formation; Pco, Connoquenessing Formation, undifferentiated; Pcou, Connoquenessing Formation, upper member; Pcom, Connoquenessing Formation, middle member; Pcol, Connoquenessing Formation, lower member; Ps, Sharon Formation; Mb, Burgoon Sandstone; Mh, Hempfield Shale; Ms, Shenango Formation.
Aquifer composition: cl, clay; gr, gravel; ls, limestone; s, sand; ss, sandstone; sh, shale.
Static water level, depth below land surface: r, reported.
Use: A, abandoned; D, domestic; I, industrial; O, observation; Ps, public supply; S, stock; T, test hole.
Remarks: Fa, field analysis in table 5; La, laboratory analysis in table 4; S, storage coefficient and T, transmissibility in table 1.

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
					BUTLER COUNTY											
Bt- 3	E3d-1454	Guy Isaces	H. I. Mong	1954	1420	Drl	4	132 r	45 r	Pkl	ss		45 r		D	
4	E3d-0449	H. A. McConnell	do.	1953	1340	Drl	5	125 r	78 r	Ph	ss		80 r		D	
5	E3d-1763	W. H. Neely	Chase		1330	Drl	4	100 r	100 r	Pv	ls	7-12-55	78.00	13	O, D	
7	E3d-6339	E. S. Cooper			1205	Drl		85 r		Ph	ss					
8	E3d-0341	J. Youshock	McWilliams	1955	1390	Drl	5	100 r	60 r	Pkl	ss	6-27-55	28.00		O	
9	E3b-7653	Paul Montgomery	H. I. Mong	1952	1365	Drl	5	95 r		Pv	ls		50 r		D	
10	E3b-7764	Richard Walter	do.	1951	1297	Drl	5	97 r	97 r	Ph	ss		18 r		D	
11	E3b-6762	W. L. Lott	J. E. Williams	1951	1340	Drl	5	26 r	26 r	Pkl	ss		11 r		D	
13	E3d-8323	C. S. Rogers		1925	1240	Drl	10	454 r	110	Pco	ss	7-13-55	73.60		O, A	Fa, La, T
14	E3d-2151	A. J. Pink	Robert Ralston	1955	1378	Drl	6	80	28	Pkm	sh	7-12-55	38.40		D	
15	E3d-7936	Harry Ripley	U. S. Dean	1955	1220	Drl	5	60 r	25 r	Pkl	ss		25 r	14	D	
17	E3d-4052	Slippery Rock Boro.	Roy Keaton		1290	Drl	10	496	92			2-23-54	90.00	30		

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
BUTLER COUNTY—Continued																
Bt- 18	E3d-6627	Crestview Farm			1120	Drl	10	373	20				flowing	200	D	La
19	E3d-7949	David McDevitt	Summerlea Inc.	1955	1200	Drl	10	310 r	20 r			11- 8-55	33.10		A	
20	E3d-3938	Slippery Rock Boro.	Pioneer Drilling Co.	1948	1300	Drl	12	105	43 r	Pkl	sh	4-30-48	39.50	50	Ps	
21	E3d-3938	Slippery Rock Boro	do.	1948	1335	Drl	8	406	185 r	Pco	ss			85 r	Ps	
24	E3d-5712	L. P. Lang	Leise Bros.	1956	1110	Drl	6	76 r	68 r			5- 7-56	0.0		D	
25	E3d-3138	Slippery Rock Boro	Roy Keaton	1953	1280	Drl	7	436	80	Pco	ss	7-30-56	14.32	45 r	O	Fa, La, T
26	E3d-2335	C. T. Ucker	Uber	1935	1240	Dug	36			Qem		7-30-56	26.43		O, D, S	
27	E3d-2131	do.			1160	Drl	5					7-30-56	flowing			
28	E3d-2331	Slippery Rock Boro.	Roy Keaton	1953	1160	Drl	8	115 r		Pcou	ss	1953	flowing r	180 r	Ps	T
29	E3d-2431	do.	do.	1953	1160	Drl	8	128 r	112 r	Pcol	ss	1953	flowing r	55 r	Ps	Fa, La, T, S
30	E3d-7427	Don Greenway	Peter Leise	1955	1200	Drl	7	90 r	70 r	Pm	sh	7-31-56	63.18	5 r	D	
31	E3d-7920	A. C. Ralston	Robert Ralston	1946	1230	Drl	4	90 r	85 r	Pcn	ss		20 r		D	
32	E3d-7618	A. R. Connell	B. C. Griffith	1953	1302	Drl	5	92 r	60 r	Pkm	sh		38 r		D	Fa
33	E3d-7518	J. Barron	U. S. Dean	1956	1310	Drl	5	89	70 r	Pkl	ss	8- 1-56	47.98		D	
34	E3d-6916	J. P. English	Deitrich		1230	Drl	6	137 r	45 r	Ph	ss				D	Fa
35	E3d-8112	C. L. Moore	Bupp	1931	1235	Drl	5	100 r		Ph	ss		58 r		D, S	Fa, La
36	E3d-8501	J. M. McCleary	do.	1925	1290	Drl		105 r					87 r		D, S	Fa

37	E3c-8063	A. G. Davis	Bupp	1930	1210	Drl	6	150 r	39 r	Ph	ss		54 r		D, S	
38	E3d-7702	Russell Brandon	Glenn Cunningham	1944	1150	Drl		165 r	155 r	Pcou	ss		75 r		D, S	Fa
39	E3c-7760	J. C. Studebaker		1928	1170	Drl	10	92	50 r			8- 2-56	5.75		S	Fa
40	E3c-8258	O. N. Studebaker		1927	1270	Drl	10	189	40	Ph	ss	8- 2-56	51.52		A, O	
41	E3c-7460	J. C. Studebaker		1896	1155	Drl	8	302	36			8- 2-56	15.74		A, O	
42	E3c-7258	O. N. Studebaker			1310	Drl		42 r	22 r	Pkm	sh		25 r		S	Fa
43	E3d-5615	J. L. Boyd	U. S. Dean	1956	1150	Drl	6	105 r	81 r	Pm	sh	8- 2-56	55.26	10 r		Fa, La
44	E3d-5618	H. W. Cooper			1100	Drl	8					8 2-56	flowing		A	Fa, La
45	E3c-7562	V. C. Bosler		1880	1140	Drl	8	745	42 r			8- 3-56	flowing		S	Fa
46	E3c-7553	D. R. Ohanlon			1230	Drl		180 r		Pcou	ss				D	Fa
48	E3d-6808	W. C. Johnson	U. S. Dean	1952	1170	Drl	5	62 r	30 r	Pv	ls		30 r			Fa
49	E3c-7362	H. T. Murphy			1105	Drl	6	106 r	90 r	Pcou					D	Fa
51	E3d-6929	Jake Friedman			1180	Drl	4	68 r	40 r	Ph	ss		28 r		D, S	Fa
52	E3d-6732	G. E. Redmond	B. C. Griffin	1950	1245	Drl	5	110 r	76 r	Pcn	ss	8- 7-56	73.70		D, O	Fa, La, T
53	E3d-6540	Earl McConnell		1915	1245	Drl	4	70 r	20 r	Pcn			35 r			
54	E3d-7242	D. W. Croll	Duffard		1130	Drl		42 r		Ph	ss		6 r			
55	E3d-7835	D. N. Carlin	Uber	1954	1165	Drl	7	105 r	105 r		gr	8- 7-56	51.20		O	
56	E3d-7941	Aaron Gutherie	Dittmer and Sons		1180	Drl		173 r	150 r	Pm	sh		64 r		D	Fa
58	E3d-7950	J. D. Lawry	Robert Ralston	1949	1240	Drl	4	111 r	40 r	Ph	ss		35 r			
59	E3d-7350	L. F. Veit		1920	1190	Drl		85 r		Ph	ss				D	Fa
60	E3d-4126	R. W. Hines	Davis and Sons	1955	1225	Drl	6	100 r	60 r	Ph	ss		40 r		D	
61	E3d-4024	J. R. Hines	Chambers	1930	1200	Drl	6	112 r	80 r	Ph	ss					Fa
62	E3d-4530	W. E. Boyd	Thornbury	1943	1320	Drl	5	100 r	60 r	Pkl			70 r			Fa
63	E3d-4629	Hoffman	Chambers		1260	Drl	5	141 r	100 r	Ph	ss		100 r		D	
64	E3d-3228	L. L. Hadley	U. S. Dean	1954	1210	Drl		36 r	8 r	Pcn	ss		15 r			Fa
65	E3d-4962	Camp Bucoco			1150	Drl		1135 r				8-15-56	flowing		A	Fa, La

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
						BUTLER COUNTY—Continued										
Bt- 66	E3d-4546	Clarence Long	Davis and Sons	1955	1260	Drl	6	70 r	31 r	Ᵽh	ss		50 r	30 r	D	Fa
67	E3d-3456	Dwayne Hartzell	Robert Ralston	1946	1320	Drl	5	154 r	16 r	Ᵽcou	ss	8-15-56	48.77		O, D, S	Fa. La
69	E3d-1662	W. H. Neely			1325	Dug	24	14		Qem		11-12-56	11.42		D, O	T
70	E3d-5950	S. R. Stoughton	W. H. Baldauf		1270	Drl	6	160 r	81 r	Ᵽcou	ss	6- 3-57	38.00	40 r	D	
71	E3b-7754	Alden McClintock	H. I. Mong	1957	1360	Drl	6	78 r	4 r	Ᵽkl	ss		58 r	8 r	D	
72	E3b-7554	Vernon Baker	V. C. Palmer	1957	1360	Drl	6	141 r	95 r	Ᵽcn	sh				D	
76	E3d-6002	T. D. Stewart	Ray McQuistion	1957	1120	Drl	6	51 r	40 r	Ᵽcn	sh	7-10-57	10.38		D	
77	E3d-7208	J. H. Homer	L. H. Mfg. Co.	1929	1188	Drl	8	1157 r	56 r						A	
78	E3d-5729	Wm. Wadsworth	Daugherty	1918	1219	Drl	8	794 r	26 r							Producing Gas Well
80	E3d-3658	Dwayne Hartzell	Eakin	1904	1297	Drl	8	777 r	40 r						A	
81	E3d-4860	L. Sankey	Grubb & Co.	1912	1242	Drl	8	1077 r	19 r						A	
83	E3d-5025	Lee Allison	Davis and Sons	1958	1257	Drl	6	110 r	95 r	Ᵽv	ls		73 r	18 r	D	La
84	E3d-4342	Slippery Rock State Teachers College			1317	Drl	6	263 r		Ᵽm	sh		130 r	50 r	Ps	
85	E3d-4341	do.	Roy Stoffard	1938	1355	Drl	12	297	500 r	Ᵽm	sh		130 r	125 r	Ps	
86	E3d-4343	do.	Penna. Drilling Co.	1953	1275	Drl	20	102 r	50 r	Ᵽcn	sh		67 r	10 r	A	
87	E3d-4442	do.	do.	1953	1280	Drl	25. 20 r, 16 r	99 r	20 r, 41 r, 64 r	Ᵽcn	ss	9-23-53	67.51	149 r	Ps	T
88	E3d-4641	do.	do.	1953	1320	Drl	10	250 r	110 r	Ᵽh	ss	12-14-53	47.90	25 r	Ps	

89	E3d-3564	John Dechant	James Thornbury	1940	1352	Drl		178 r	135 r	Pcou	ss	138 r	5 r	D	
90	E3d-3061	Wm. Campbell	H. I. Mong	1949	1345	Drl		211 r		Pcou	ss				
91	E3d-2864	Howard McCandless	B. C. Griffin	1956	1337	Drl	6	67 r	20 r	Ph	ss	30 r		D	
92	E3d-3865	do.	H. I. Mong		1340	Drl	5	80 r	30 r	Ph	ss	30 r			
93	E3d-4157	N. F. Doerr	Davis and Sons	1955	1285	Drl	6	170 r	60 r					D, S	
94	E3d-5792	Floyd Osborne	do.	1957	1223	Drl	6	76 r	9 r	Ph	ss	35 r	16 r	D	
95	E3d-5655	W. P. Gallagher	do.	1957	1248	Drl	6	108 r	49 r	Ph	ss	60 r	30 r		
96	E3d-4635	C. D. Renick			1330	Drl		101 r		Ph	ss			D	
98	E3c-8452	Frank Book	Davis and Sons	1957	1295	Drl	6	92 r	61 r	Pkl	ss	35 r		A	Fa, La
99	E3d-5709	Slippery Rock U. P. Church	do.	1958	1168	Drl	6	65 r	36 r	Pv Pcn	ls ss	28 r			
100	E3d-6051	P. E. Kennedy	do.		1177	Drl	6	108 r	61 r	Ph	ss	42 r	32 r		
101	E3d-5142	William Fenick			1310	Drl	6		43 r	Pcn	sh	105 r	16 r		
102	E3d-6458	Richard Wolford	Davis and Sons		1181	Drl	6	98 r	41 r	Ph	ss	30 r	36 r	D	
104	E3c-9848	Floyd Book	Peter Leise	1948	1339	Drl	7	258 r	250 r	Pcou	ss	100 r		D, S	Fa
105	E3d-6553	Crosby Spencer	H. I. Mong	1945	1180	Drl									
106	E3d-7055	William Hall	Suess	1950	1245	Drl		51 r	35 r	Pcn				D	
107	E3d-7259	A. P. Labor	Davis and Sons	1956	1250	Drl		85 r		Pcn	sh				
108	E3d-7461	Elmer Holland	do.	1956	1267	Drl	6	127 r	56 r	Ph	ss	60 r			
110	E3d-7835	West Liberty Methodist Church	Suess		1266	Drl		65 r		Pcn	sh				
111	E3d-7963	Albert Alexander	U. S. Dean	1957	1238	Drl	5	70 r	16 r	Pkl	ss	35 r			
112	E3d-6051	J. A. Birckbichler	W. H. Baldauf	1957	1172	Drl	6	152 r	60 r					D	
131	E3d-4538	Robert Kaufman	U. S. Dean	1959	1323	Drl	8	102 r	8 r	Pv	ls	87 r			Fa
132	E3d-5807	J. Myers	do.	1959	1170	Drl	5	71 r	29 r	Pcn	sh	30 r			
134	E3d-4665	R. F. Horrell	Andrew Beikert	1957	1273	Drl	6	74 r	18 r	Ph	ss	45 r		D	
135	E3d-4546	D. L. Mershimey	Davis and Sons	1957	1266	Drl	6		21 r	Ph	ss	40 r	30 r		Fa

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
							BUTLER COUNTY—Continued									
Bt- 136	E3d-4647	Wm. Jefferies	Davis and Sons	1957	1242	Drl	6	85 r	42 r	ℙh	ss		35 r	30 r		
137	E3d-4546	A. T. Causer	do.	1957	1238	Drl	6	74 r		ℙh	ss			30 r		
138	E3d-6352	Carl Morse	do.	1959	1180	Drl	6	82 r	31 r	ℙh	ss	9-21-59	39.18	30 r		
139	E3d-6860	Bennie LeDonne	do.	1959	1150	Drl	6	34 r	21 r	ℙh	ss		15 r	18 r		
140	E3d-6657	Thomas McGuire	do.	1959	1180	Drl	6	73 r	41 r	ℙh	ss		30 r	30+ r		
141	E3d-5857	J. L. Greaves	do.	1959	1250	Drl	6	104 r	53 r	ℙh	ss		57 r	30 r		Fa
142	E3d-6324	R. J. Steiner	do.	1958	1132	Drl	6	126 r	108 r	ℙm	sh		27 r	30 r		Fa
143	E3d-1362	E. Cooper	W. H. Baldauf	1959	1338	Drl	6	160 r	86 r	ℙh	sh		88 r	30 r		
144	E3d-1362	Louis Ciochette	do.	1959	1340	Drl	6	150 r	92 r	ℙcn	ss		72 r	20 r		Fa
145	E3d-2557	Calvin Hogg	Davis and Sons	1959	1303	Drl	6	85 r	52 r	ℙcn	ss		31 r	30 r		Fa
149	E3d-6003	Lou Maycrott	do.	1959	1123	Drl	6	72 r	29 r	ℙh	ss sh		25 r	8 r		
152	E3d-7924	M. C. Swope	Andrew Beikert	1948	1216	Drl	6	71 r	47 r	ℙcn	ss		30 r	15 r		Fa
153	E3d-3748	Dean Reep	Hugh Collins	1959	1338	Drl	6	64 r	42 r	ℙkl	ss		28 r	25 r		
154	E3d-2252	Wilson Pink	Robert Ralston	1959	1365	Drl	5	60 r	40 r	ℙkm	sh		45 r	30 r		
155	E3d-7919	B. S. Miller	L. H. Mfg. Co.	1926	1200	Drl	8	776 r	176 r						A	
156	E3d-7918	do.	do.	1926	1200	Drl	8	795 r	155 r						A	
157	E3d-7915	do.	do.	1926	1170	Drl	8	1110 r	143 r						A	
158	E3b-1244	J. C. Hockenberry	do.	1944	1270	Drl		10,096 r							A	

	159	E3d-6859				1400	Drl		233							A	
	160	E3d-1244	J. J. McGarvey			1269	Drl		169							T	
	161	E3d-1334	D. Brenneman			1328	Drl		164							T	

LAWRENCE COUNTY

La-	91	E3c-1257				1242	Dug	36			Qo		6-23-53	6.71		A	
	93	E3c-1250	Mrs. Lena Rogers			1270	Dug	48	15.3		Qal		6-23-53	1.86		D	
	95	E3c-1154				1280	Dug	48	16.3		Qo		6-23-53	6.22		D	
	96	E3c-1052	Rev. H. A. Palding	Clifford Book	1951	1280	Drl	6	100+		Pcn	sh				O	
	97	E3c-1152	do.			1280	Dug	48	39.5		Qem		6-23-53	8.93		O	
	98	E3c-1008	James Hohman	F. O. Offutt		1260	Drl	8	62.4	59 r	Pcn	sh	6-23-53	18.70		D, S	Fa
	99	E3c-1048	do.			1260	Dug	54	10.4		Qem		6-23-53	6.22			
	100	E3c-1448	C. J. Uber	F. O. Offutt	1941	1275	Drl	6	70		Pkl	ss		40 r			
	101	E3c-1548	R. R. Beach			1285	Dug	36	13		Qgm		6-23-53	3.61			
	102	E3c-1548	do.	Holmes		1285	Drl	6	137		Ph	ss		80.00		D	
	105	E3d-3301	T. S. Minor	Munn	1927	1250	Drl	8	67 r		Pv	ls		57 r		D, S	
	106	E3c-2247	Alex Resnik	Book		1295	Drl	6	90 r		Pcn					D	
	107	E3c-1436	F. Guarnieri	F. O. Offutt		1290	Drl	6	76.2	80 r	Pcn	ss sh	6-24-53	56.18		O, D, S	Fa, La
	108	E3c-1437	do.	do.	1948	1290	Drl	6	80 r	35 r	Pcn	ss sh		54 r	3 r	D, S	
	110	E3c-3550	W. P. Gradner			1210	Drl	4	65 r					34 r		D, S	
	111	E3c-3754	Mrs. Clara Seth	F. O. Offutt	1929	1210	Drl	5	75 r		Qem	gr		30 r		D, S	
	114	E3c-4254	Paul Shoaff			1210	Dug		10.9		Qem	gr	6-24-53	5.70		D	
	115	E3d-5201	P. A. Corry	Dillon		1190	Drl	6	64 r		Ph	ss				S	
	116	E3c-5556	Mrs. A. Ithen			1150	Drl	6	160 r		Qem		6-25-53	33.40		D	T
	117	E3c-4864	P. B. Rodgers	Kneram	1943	1160	Drl	5	87.3		Pm		6-25-53	17.47	2.5 r	D, S	T
	118	E3d-4006	C. A. Glenn			1240	Dug				Qem			14 r		D	

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
							LAWRENCE COUNTY—Continued									
La- 130	E3c-6452	C. A. Richeal			1110	Drl	6	81.1		Qo		6-25-53	30.08		D, S	T
131	E3c-6636	C. M. McCormick	Book	1928	1270	Drl	4	140 r		Ph	ss	6-25-53	45 r	12 r	D, S	
134	E3c-7037	M. D. Grossman			1195	Dug	48	13.7		Qem		6-25-53	3.77		O	
135	E3c-5447	C. Hohman	U. S. Dean	1953	1175	Drl	6	122 r	110 r	Pm	sh				D	
136	E3c-5040	do.			1260	Dug		13.9		Qem		6-26-53	4.27		S	
137	E3c-5041	do.		1950	1260	Dug		14 r		Qem	gr		5 r		D	
138	E3c-4061	Ray Foster			1230	Dug		11.3		Qgm		6-26-53	6.63		D, S	
150	E3c-5637	R. Pebbles	Book		1220	Drl	5	222	12			7- 2-53	7.70		S	Fa, La
151	E3c-1123	R. Bobbert			1290	Drl	6	105 r		Pcn		7- 2-53	14.87		D, O	
155	E3c-3035	R. M. Conahy		1952	1225	Dug		15.1		Qem		7- 2-53	10.88		S	
156	E3c-4347	W. Cunningham			1170	Drn	1	8 r		Pv	ls		6 r		D	
157	E3c-3931	T. J. McConahy			1260	Drl	6	96 r		Pcn	ss		50 r		D, S	
158	E3c-3931	do			1260	Dug	6	23.2		Pkm	ss	7- 2-53	19.33		D	
159	E3c-3024	C. Bayne			1320	Dug		20.8		Qem		7- 2-53	8.56		D	
171	E3c-2124	Gilmore			1295	Drl	8	100 r				7- 3-53	57.17		O	
172	E3c-1130	W. Boyd			1220	Drl	10	331.5	47			7- 7-53	6.83		A	
173	E3c-1933	S. P. Campbell			1240	Drl	5	145 r					34 r		D, S	
178	E3c-0602	R. Brown			1240	Dug		19.4		Qo		7- 8-53	5.56		D	

182	E3c-7837	Jake MacCracken		1922	1070	Drl	6	1300 r					flowing	S	Fa, La
190	E3c-1715	J. McConhay			1250	Dug		24.1		Qem		7- 8-53	7.93	D, S	
191	E3c-1714	do.			1255	Dug		15.7		Qem		7- 8-53	1.53	D, S	
192	E3c-1210	do.			1255	Drl	4	95				1-25-54	85.52	O, D	
193	E3c-1210	do.			1260	Drl	9	900 r				1-25-54	70.81	O	
194	E3c-2811	T. Gibson Martin			1220	Drl	4	94		Ph	ss	7- 8-54	19.04	O, D, S, T	
195	E3c-3613	T. G. Stevenson			1260	Dug		15		Qem		7- 8-53	4.15	D, S	
196	E3c-4024	Perry Book	U. S. Dean	1949	1270	Drl	6	44 r	20 r	Pkl	ss		18 r	D, S	
197	E3c-2402	Sam McGary	Clifford Book	1947	1285	Drl	5	96 r		Pkl	ss	7- 8-53	65 r	D, S	
199	E3c-4205	John Sides			1255	Dug		17.6		Qem		7- 9-53	6.81	D	
211	E3c-5618	R. G. Mayberry	R. N. Brown	1948	1200	Drl	4	84.5		Ph	ss	7- 9-53	14.33	O	
212	E3c-5719	do.		1952	1200	Drl	4	53 r		Pcn	sh		18 r	O	
213	E3c-5707	A. E. Hunter	U. S. Dean	1950	1200	Drl	5	85 r		Pcn	sh		60 r	D	
214	E3c-6327	B. Jameson	do.		1200	Drl	5	87 r		Pcn	sh			D	
216	E3c-6708	G. Gilson	do.		1180	Drl	6	180 r				7- 9-53	49 r	D, S	
217	E3c-7709	J. Shultz			1245	Dug		22.7		Qem		7- 9-53	7.45	D	
219	E3c-8413	Norman Hunt	Dean Sr.	1911	1245	Drl	4	70 r	60 r	Pkl	sh		35 r	D, S	
230	E3c-8214		U. S. Dean	1951	1260	Drl	5	40 r		Pkm			25 r	D	
231	E3c-7726	E. Barch			1280	Drl	4	85 r		Pcn			55 r	D. S	
232	E3c-8725	do.			1290	Dug		12.3		Qem		7- 9-53	2.71	O	
233	E3c-8431	Stuart			1090	Dug		20 r		Qem			9 r	D	
234	E3c-7431	W. Kneram	Book & Dean		1225	Drl		77 r		Pcn	sh		33 r	D	
347	E3c-1327	Earl Nelson			1230	Drl	10		16			1-25-54	19.32	O	
417	E3c-1436	do.			1220	Drl	10	436	52						
418	E3c-1326	do.			1255	Drl	10	271	20			6-10-60	46 r	A	
421	E3c-1729				1240	Drl	7	76.5		Ph	ss	1-25-54	34.14	O	

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
						LAWRENCE COUNTY—Continued										
La- 422	E3c-7709	J. Shultz	John McQuistion		1240	Drl	4	100	99 r	Ph	ss	1-27-54	81.00			
423	E3c-0717	L. Burk	F. O. Offutt	1950	1380	Drl	6	299 r	140 r	Pcn						
424	E3c-1516	James Cooper		1905	1378	Dug	48	13.5		Qem		6-30-55	7.82		D	
425	E3c-1326	Earl Nelson		1909	1255	Drl	10	740	35			7-19-55	36.75		A	
426	E3c-1426	do.		1909	1258	Drl		266	42			7-19-55	36.23		A	
427	E3c-1427	do.		1909	1242	Drl	8	266	42			7-29-55	23.90		O	
428	E3c-1227	do.		1909	1270	Drl	7	710	34			7-19-55	44.84		A	Fa
429	E3c-1128	do.		1909	1225	Drl	8	812	28			7-21-55	26.86		A	
430	E3c-1229	do.		1905	1234	Drl	10	275	50			7-26-55	4.15		A	
431	E3c-1229	do.		1909	1235	Drl	8	675	40			7-26-55	6.33		A	
432	E3c-1328	do.		1909	1238	Drl	8	850	50			7-29-55	13.80		A	
433	E3c-2721	Charles Kubler			1315	Dug		30		Qo		6-30-55	7.39		D	
434	E3c-5126	C. E. Craig	Bupp	1939	1263	Drl	4	90 r	46 r	Pkl	ss		60 r		D	
435	E3c-6029	J. L. Reynolds	U. S. Dean	1949	1195	Drl	4	80 r	40 r	Ph	ss		25 r		D	
436	E3c-7032	D. McMichaels	do.	1953	1150	Drl	5	61 r	45 r	Pm	sh	6-30-54	36.30	6 r	D	
437	E3c-7231	L. M. Mathewson	do.	1953	1190	Drl	5	54 r	10 r	Pkl	ss		40 r	10 r	D	
438	E3c-5556	Roy Dight	F. O. Offutt	1954	1161	Drl	6	179 r	167 r	Pco	ss		48 r	20 r	D	
439	E3c-4355	H. P. Wallace	do.	1943	1183	Drl		100 r	100 r	Qem			40 r	15 r	D	

440	E3c-2547	Glenn Hillmar	do.	1954	1250	Drl	5	80 r		Pkl	ss		35 r	6+ r	D	
441	E3c-1247	Hohman	do.	1935	1280	Drl	4	135 r	125 r	Ph	ss		70 r		D, S	
462	E3c-0305	Dewey K. Smith			1325	Dug	24	10		Qgm		9-19-56	1.00		O	Fa
463	E3c-0305	do.	Parshall Bros.	1904	1330	Drl	4	49	25 r	Pkm		9-19-56	19.90		O	
464	E3c-0602	Charles Lowery		1956	1250	Drl	6	125 r	27 r	Ph	ss				D	Fa
465	E3c-0605	Eugene Hedglan			1360	Dug		22 r		Qo			5.18		D	Fa
468	E3c-1021	Frank Gargasz			1320	Drl	6	80 r		Pkl			35 r		D	
469	E3c-1020	Roy Donley			1290	Dug	36	22 r		Pkl		9-20-56	4.83		D	Fa
470	E3c-1020	do.			1290	Drl	4		20 r	Pkl	ss				D	
472	E3c-4225	Carl A. Barkand			1250	Drl	6	83	40 r	Pcn	ss	9-20-56	42 r		D	Fa
473	E3c-1514	Frank Bronson			1350	Dug	60	19		Qem		9-20-56	6.01		D	Fa
474	E3c-0901	Paul C. Michaels			1100	Drl	4	72 r	60 r	Pcol			7 r		D	Fa
476	E3c-1917	H. L. Cooper			1375	Dug	36	19		Qem		9-21-56	2.80		S	Fa
477	E3c-2505	C. Stewart			1300	Drl	6	93 r		Pkl	ss				D, S	Fa
478	E3c-2512	W. A. Shields			1240	Dug	36	14				9-21-56	6.82			Fa
479	E3c-1217	Myers Hoffman			1280	Drl	8	290	80			5-15-57	64 r		A	
480	E3c-1226	Earl Nelson			1290	Drl	8	850	20			12- 8-56	55		O	Fa
481	E3c-6158	George Graham			1160	Drl	6	90 r		Pcou		12- 6-56	58.44		D, S	Fa
482	E3c-6355	C. W. Hohman			1100	Drl	6	42 r	42 r	Qo	s, gr		27 r		D	Fa
483	E3c-7049	C. Murray			1170	Dug		26.8		Qem		12- 6-56	20.75		S	Fa
484	E3c-7039	G. E. Stoughton	Clifford Book	1940	1150	Drl	5	105 r					90 r		D	Fa
485	E3c-8242	I. A. Livingston	Floyd Book	1940	1235	Drl	5	54 r		Pkl	ss	12-13-56	5.37		D	Fa, T
486	E3c-7745	Harry Campbell	Robert Ralston		1220	Drl	4	90 r					30 r			Fa
487	E3c-7746	do.			1200	Drl	8	51				12-13-56	11.59			
488	E3c-6350	Glenn Moorhead			1150	Dug		35 r		Qo			20 r		D	Fa
489	E3c-6249	C. R. Martin	Floyd Book	1923	1180	Drl		81 r	60 r	Ph	ss		40 r		D, S	Fa
490	E3c-6247	John Dudash			1200	Drl		102 r		Pcou	ss				D	Fa

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
							LAWRENCE COUNTY—Continued									
La- 491	E3c-6245	George Book			1210	Drl		80 r		Ph			20 r		D	Fa
492	E3c-7125	A. Hoover			1270	Drl		70 r		Qem	s, gr		35 r		D	Fa
493	E3c-7223	John Turner	Clifford Book	1945	1280	Drl	4	63 r	50 r	Pkl	ss		50 r		D	Fa, La
494	E3c-7516	John Morrow		1942	1290	Drl		70 r		Pkl	ss	5- 8-57	37.65		D	Fa
495	E3c-7919	C. N. Bruce			1300	Dug		28 r		Qem			10 r		D	
497	E3c-8023	W. E. McFarland			1270	Drl		80 r		Pcn					D	Fa
498	E3c-7824	Gilbert Houston	U. S. Dean	1952	1300	Drl		98 r	80 r	Pv	ls				D	Fa
499	E3c-6801	Mrs. E. Heckthorne	Kneram		1165	Drl		80 r	80 r	Qo	s, gr	5- 8-57	51.31		D	Fa
500	E3c-7205	John Dolougham	George Book	1941	1180	Drl		107 r	107 r	Qo	gr		40 r		D, S	Fa
501	E3c-7206	do.			1180	Dug		22 r		Qo		5- 8-57	7.09		D	Fa
502	E3c-6305	Lester Dicks			1200	Dug				Qem					D, S	Fa
503	E3c-6311	G. Kronstad			1180	Drl	4	72 r				5- 8-57	44.18			
504	E3c-6606	Minnie and Alvin McFarland			1200	Dug		15 r		Qo					D	Fa
505	E3c-6317	do.			1210	Drl	6	80 r				5- 8-57	27.07			Fa
506	E3c-6826	Mike Dudash	U. S. Dean	1950	1260	Drl	5	110 r	60 r	Pv	ls	5- 8-57	56.00		D	Fa
507	E3c-5713	J. C. Post			1200	Drl	6	70 r					30 r			Fa
508	E3c-4621	George McConahy	V. C. Palmer	1956	1270	Drl	8			Pkl	ss		40 r	5 r	D, S	Fa
510	E3c-5002	H. W. Brua	U. S. Dean	1952	1200	Drl	5	60 r	25 r	Pkl	ss		23 r	6 r		Fa

511	E3c-3606	J. M. Wimer			1275	Dug	48	28 r		Qem			21 r			Fa
512	E3c-3102	H. P. Neithercoat			1290	Drl	4					5- 9-57	41.10		D, S	Fa
513	E3c-6530	H. A. McCracken		1927	1180	Drl	4	44 r		Ph		5-10-57	15.92		D	Fa
514	E3c-5527	Joseph Mariotti		1950	1240	Drl	5	95 r	60 r	Pkl	ss	5-10-57	32.88			Fa
515	E3c-4625	E. W. Shaw	Book, Sr.	1923	1240	Drl	4	70 r	18 r	Pkl	ss		40 r		S, D	Fa
516	E3c-3021	E. M. Hillard			1340	Dug	48	22 r		Qem	gr, cl		12 r		D	Fa
517	E3c-3223	C. Davis	Davis and Sons	1954	1230	Drl	5	46 r	44 r	Qem	gr		21 r	18 r		Fa
518	E3c-3639	Clyde Adams			1200	Drn	4	18 r		Qem			11 r			Fa
519	E3c-3444	M. L. Minor			1230	Drl		90 r								Fa
520	E3c-3953	Joe Shoaff	Kneram & Barter	1943	1225	Drl	8	186 r		Pco	ss		50 r		D	Fa
522	E3c-4134	John C. Hoye	U. S. Dean	1952	1260	Drl	6	100 r	60 r						D, S	Fa
523	E3c-2737	Bill McConahy	do.	1955	1210	Drl	6	50 r	50 r	Qo			6 r			Fa
524	E3c-2737	do.			1210	Drn	1	7 r		Qo					D	Fa
525	E3c-2643	Bert Gargasz	F. O. Offutt	1952	1200	Drl		62 r	62 r	Qem	s, gr		20 r		D	Fa
526	E3c-5034	James R. McDeavitt			1200	Drl	4	60 r		Ph	ss	5-11-57	24.67		D, S	Fa
527	E3c-4445	Wade M. Lutz	U. S. Dean	1956	1180	Drl		55 r	33 r	Pcn	sh				D	
528	E3c-3044	Ralph Montgomery	F. O. Offutt	1954	1220	Drl	6	86 r	86 r	Qem	gr		20 r		D, S	Fa
529	E3c-2752	F. J. Kutzner		1930	1210	Drl	4	100 r					10 r		D	Fa
530	E3c-2363	Charles Stroscheim			1220	Drl	4	130 r					30 r		D	Fa
531	E3c-3564	Robert Burns	H. I. Mong	1946	1205	Drl	4	85 r	75 r				17 r		S	Fa
532	E3d-3708	Harry Bruner	F. O. Offutt	1930	1220	Drl		52 r		Pv	ls		10 r		D, S	Fa
533	E3c-6053	W. H. Barchat	Book & Proch	1957	1140	Drl	6	162 r	139 r	Pcou	ss		34.36	36 r	D	La, Fa
534	E3c-7610	Mildred Allison	U. S. Dean		1255	Drl	5	105 r	87 r	Pcn	ss		85 r		D	
612	E2d-7659	Laurel Joint School	Robert Slaven		1260	Drl	8	304	145	Ph Pcou	ss	4-30-57	128	60	Ps	
638	E3c-1603	H. McAnallen	Book & Proch	1957	1220	Drl	5	91 r	28 r	Pm			65 r		D	La, Fa
662	E3c-4141	W. J. & N. A. Offutt	Uriah Supples	1903	1201	Drl	8	777 r	42 r				flowing		A	

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
LAWRENCE COUNTY—Continued																
La- 663	E3c-4342	B. A. Pollock	Uriah Supples	1904	1187	Drl	8	825 r	64 r				flowing		A	La
664	E3c-4441	Ramsey	do.	1903	1214	Drl	8	819 r	73 r						A	
665	E3c-4835	Robert C. Shaw	Sankey & F. L. Book	1904	1265	Drl	8	813 r	22 r						A	
667	E3c-4843	Hammersmith	Uriah Supples	1903	1224	Drl	8	1020 r	36 r						A	
669	E3c-3264	Mrs. R. S. Minor	L. & H. Mfg. Co.	1916	1210	Drl	8	788 r	134 r						A	
674	E3c-5339	Frank C. Brown	Uriah Supples	1903	1245	Drl	8	1025 r	24 r						A	
675	E3c-5155	R. F. Darsie	Robert Ralston		1174	Drl		137 r	137 r	Qem	s					
676	E3d-3871	W. J. Marlowe	U. S. Dean	1954	1210	Drl		105 r	88 r	Ph	ss		29 r			Fa
677	E3d-3006	George English	do.	1948	1266	Drl		80 r	38 r	Pkl	sh		20 r		D	Fa, La
678	E3c-1357	K. Hondes	Robert Ralston	1952	1256	Drl	6	87 r	77 r	Ph						
679	E3c-4355	Slippery Rock U. P. Church			1156	Drl	5	104 r	104 r	Qem	gr					Fa
695	E3c-7734	Charles W. Groff	Book & Proch	1957	1145	Drl	5	57 r	48 r	Ph	ss		21 r		D	Fa, La
696	E3c-7432	L. Reynolds	U. S. Dean	1958	1158	Drl	6	79 r	38 r	Ph Pm	ss, sh		28 r			La
697	E3c-6915	Dean	Dean Sr.		1262	Drl		54 r	40 r	Pkm	sh		10 r			
698	E3c-7015	do.	U. S. Dean		1257	Drl	4	56 r	40 r	Pkm	ss		flowing 8 mo/yr			
699	E3d-6339	Howard Glenn	do.	1952	1260	Drl		38 r		Pkl			20 r		D, S	

700	E3c-6344	C. L. Rouser	Elmer Book	1947	1220	Drl	6	185 r	170 r	Pco	ss	85 r		D	
701	E3c-5927	Thomas Candito	U. S. Dean	1952	1245	Drl	6	76 r	31 r	Pkl	ss			D	
702	E3c-6332	Walter List	do.		1185	Drl			66 r	Ph	ss	35 r		D	
703	E3c-5041	George Hohman	do.		1263	Drl		95 r	58 r	Pkl Pv	sh ls,	73 r			
704	E3c-4826	Circle R. Farm	do.	1953	1276	Drl		140 r	30 r	Ph	ss				
709	E3c-7248	Ralph Taylor	Davis & Sons	1957	1160	Drl	6	112 r	41 r	Pm	sh	35 r	10 r		
710	E3c-2406	Harold McConnell	U. S. Dean	1958	1250	Drl	6	84 r		Pcn	ss	51 r	12 r		
711	E3c-8541	G. Book	Bartley	1938	1252	Drl		92 r		Ph	ss	22 r			
712	E3c-8544	C. Book	U. S. Dean	1957	1306	Drl		78 r		Pkm	sh	40 r			Fa, La
713	E3c-0508	Joe Fulkerson	F. O. Offutt	1958	1254	Drl	6	84 r	60 r	Ph	ss				
714	E3d-0662	Ernest Carr	U. S. Dean	1959	1029	Drl	6	46 r	26 r			26 r			
716	E3c-5604	James Moore	Andrew Beikert	1958	1130	Drl		72 r	30 r	Ph	ss	25 r	5 r		
718	E3c-3639	Clyde Adams	Elmer Book	1958	1200	Drl	6	114 r	57 r	Pcou	ss	11 r	300 r		
720	E3c-4360	Edwin Fitzgerald	do.	1953	1175	Drl		55 r	55 r	Qem	gr				Fa
722	E3c-5112	David Smith	do.	1958	1200	Drl	5	50 r	30 r	Pcn	ss	20 r			
723	E3c-5612	L. P. Cwynar	do.	1952	1175	Drl		58 r							Fa
724	E3c-6401	Herbert Wilson	Clifford Book	1944	1185	Drl		57 r	20 r	Pv	ls	24 r			
725	E3c-7530	Fred Hammerschmidt			1240	Dug		35 r		Qem		30 r			
726	E3c-6623	F. McElwain	U. S. Dean	1959	1250	Drl	5	117 r	80 r	Pcn	ss	62 r			
727	E3c-6809	Don Ziegler	do.	1959	1200	Drl	5	105 r	105 r	Qo	ss, gr	55 r			
728	E3c-7201	Lawrence Goodwin	Clifford Book	1950	1130	Drl		69 r	69 r	Qo					
730	E3c-7602	R. E. Fleming	U. S. Dean	1951	1120	Drl	5	44 r	44 r	Qo		flowing			
731	E3c-8903	Clair Houk	do.	1953	1120	Drl		57 r	57 r	Qo	s, gr	17 r			
732	E3c-8408	R. F. Blair	Floyd Book	1928	1172	Drl	3	128 r	100 r	Pcou	ss	40 r			Fa
733	E3c-7605	Raymond McCracken	Book & Proch	1956	1147	Drl		86 r	86 r	Qo	s				
734	E3c-3422	J. Donley	Pilgrim Coal Co.	1958	1370	Drl		150 r	140 r	Pkl	ss				

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
						LAWRENCE COUNTY—Continued										
La- 737	E3c-6926	W. McFarland	U. S. Dean	1959	1260	Drl		146 r	66 r	Pcn	ss		100 r		D	Fa
739	E3c-5834	Edward Voiture	do.	1959	1259	Drl	5	95 r	30 r	Pcn	sh	9-24-59	50.20			
740	E3c-6033	A. L. Mansfield	do.	1959	1239	Drl	5	75 r	15 r	Pcn	ss	9-24-59	38.92	12 r		
741	E3c-5934	Francis Smith	do.	1959	1234	Drl	5	78 r	12 r	Pkl	ss					
742	E3c-1415	N. R. Stoner	do.	1957	1373	Drl		165 r		Pcn	coal					Fa
744	E3c-3005	Earl Kretzer	do.	1957	1279	Drl	6	81 r	48 r	Pkl	ss		43 r	24 r		Fa
745	E3c-6406	Coachman Club	do.		1185			80 r	75 r	Ph	ss					
						MERCER COUNTY										
Mr- 3	E3b-1324	F. Campbell	F. O. Offutt	1948	1340	Drl	6	102 r	50 r	Pcou	ss			7 r	D, S	
4	E3b-1010	Mrs. M. M. Batty		1944	1345	Drl		78 r		Qgm	s		33 r		D	
5	E3b-5227	W. G. Thorn			1305	Drl	6	110 r	65 r	Pcou	ss		30 r			
6	E3b-5432	Eugene John			1330	Drl	4	180 r	60 r	Pm	sh		80 r		D, S	
7	E3b-4600	G. W. Geissenhain	B. C. Griffin	1954	1351	Drl	4	85 r	71 r	Pcn	ss		44 r		D	
8	E3b-6929	John L. Rodgers	H. I. Mong	1952	1335	Drl		121 r	40 r	Ph Pv					D	
9	E3a-8411	Fyffe	U. S. Dean	1952	1325	Drl	4	80 r	32 r	Pkl	ss		36 r		D	
10	E3a-7159	Joe Gammon	F. O. Offutt	1952	1288	Drl	6	73 r	46 r	Ph	ss			8 r		
12	E3d-0232	Neal Brown	McWilliams	1954	1320	Drl	6	55 r		Pkl		6-20-55	22.48		D	Fa

13	E3b-4821	J. E. West	N. L. Case	1955	1290	Drl	5	70 r	65 r	ℙh	ss		28 r		D	
14	E3b-4322	Raymond Duncan, Jr.	B. C. Griffin	1954	1330	Drl	6	58 r	56 r	ℙh	ss		15 r		D	
15	E3b-3922	Edward Dumbroski	do.	1953	1321	Drl	4	107 r	83 r	ℙm			16 r		D	Fa
17	E3b-1723	G. McDowell		1919	1358	Drl	5	84 r	20 r	ℙh	ss		35 r		D, S	Fa
18	E3b-1325	Jay Tiche	B. C. Griffin	1954	1345	Drl	5	56 r	32 r	ℙm	sh	1954	20 r	25 r	D	
19	E3b-0225	Paul Baer	H. I. Mong	1952	1369	Drl	5	87 r	44 r	ℙcou		6-20-55	46.26		O, D	Fa, La, T
20	E3b-0245	C. F. Westlake		1943	1360	Drl	5	52 r		Qem			18 r		D	
21	E3b-0748	Raymond Jamison			1340	Dug	24	28		Qem		6-21-55	16.50		O, D	Fa
22	E3b-1439	LeRoy Campbell		1933	1395	Drl	4	112 r		Qem			38 r	12 r	D	
23	E3b-1355	C. M. Boylan	B. C. Griffin	1948	1432	Drl	5	65 r	12 r	ℙh	ss		21 r		D	
24	E3b-2754	W. N. McCoy	Erb	1905	1350	Drl	3	68		ℙh	ss		22 r		D	
26	E3b-4653	Clyde Danker	H. I. Mong	1947	1312	Drl	6	75 r	60 r	ℙh	ss		flowing		D	Fa
27	E3b-5337	J. B. Kerr	Kerr, Sr.	1898	1343	Drl	3	96		ℙh	ss	6-21-54	64.41		O	
28	E3b-5236	do.		1907	1330	Dug		15		Qem		12-21-55	3.31		O, D, S	Fa, La, T
29	E3b-7444	B. N. Pardoe			1293	Drl	5	65 r		ℙcn			35 r		D	
31	E3b-6925	T. Campbell			1287	Drl	6	72	53 r	ℙcn		7-21-55	18.65			Fa
32	E3b-6509	F. J. Strauser	W. G. McDowell	1955	1241	Drl	6	50 r	50 r	Qo	s, gr		15 r		D	
33	E3b-6400	LeRoy McKnight	LeRoy McKnight	1945	1264	Drl	4	63 r	63 r	Qo			12 r		D	
35	E3b-4607	W. B. McDowell	F. O. Offutt	1952	1300	Drl	4	51 r	51 r	Qo	s, gr		16 r		D	
36	E3b-4009	John Miller	do.	1952	1308	Drl	6	85 r	85 r	Qem	s, gr			15 r	D	
37	E3b-4915	C. Taylor		1955	1310	Drl	6	100	94 r	ℙm	sh	6-22-55	47.50		D	Fa
38	E3b-3210	C. Sowers	H. I. Mong	1954	1342	Drl		106 r	67 r	ℙh	ss		86 r	10 r	D	
39	E3b-2309	H. L. Doersh	B. C. Griffin	1953	1380	Drl	6	101 r	95 r	ℙh	ss		70 r	22 r	D, S	
40	E3b-1310	Jack O. Robson	H. I. Mong	1953	1370	Drl	6	86 r	86 r	Qgm			35 r		D	
41	E3b-0509	A. M. Roberts	F. O. Offutt	1938	1373	Drl		90 r	80 r	ℙh	ss		70 r		D	
42	E3b-0012	A. F. Sagulla	V. C. Palmer	1955	1364	Drl	6	77	40 r	ℙh	ss	7-14-55	48.30		O, D	Fa, La, T
43	E3a-0164	O. Wright	F. O. Offutt	1932	1360	Drl		120 r	27 r	ℙh	ss		60 r	10 r	D	

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
						MERCER COUNTY—Continued										
Mr- 44	E3a-0652	Paul Anderson			1300	Dug	36	20 r		Qo		6-22-55	6.31	15 r	O, D	Fa
45	E3a-2039	E. L. Peters		1930	1280			65 r		Pm	sh		25 r		D, S	
46	E3a-5322	G. J. Sheffer	G. J. Sheffer	1890	1310	Dug		21		Pcn	sh	6-24-55	5.23		O. D	Fa
47	E3a 3353	A. J. Guest		1940	1380		5	195 r		Pco			20 r		D	
48	E3a-3042	A. Pyle	F. O. Offutt		1340	Drl	6	100 r		Ph	ss	6-24-55	31.30		D, S	Fa
49	E3a-2422	Ralph Butch	do.	1952	1240	Drl		50 r	30 r	Pcou	ss		16 r	7 r	D	
50	E3a-3134	J. H. Fitzgerald	do.	1930	1350	Drl	5	69 r	69 r	Pcn	sh		20 r	15 r	D	
51	E3a-3133	Charles McClure	V. C. Palmer	1955	1360	Drl	5	60	27 r	Pcn	sh	6-27-55	36.65		O, D	Fa, La
52	E3a-3642	Robert Rupert	do.	1955	1342	Drl	6	141	76.5 r	Ph	ss	6-21-55	83.84	20 r	D	Fa
53	E3a-4049	Thomas Campbell	F. O. Offutt	1949	1310	Drl	4	85 r	61 r	Ph	ss		27 r	8 r	D	
55	E3a-5142	Platt		1930	1321	Drl	6	85 r		Ph	ss		55 r		D	
56	E3a-5840	C. L. Williams		1949	1305	Drl	6	100 r		Ph	ss	6-24-55	54.01			
57	E3a-5034	R. C. Barber			1320	Drl		60 r		Ph	ss	6-22-55	4.51		O, D, S	Fa, La
58	E3a-4022	John Courtney	F. O. Offutt	1950	1225	Drl	5	70 r	56 r	Pcou	ss		40 r		S	
59	E3a-3116	C. N. Nye	C. N. Nye	1955	1180	Dug	30	12 r	4 r	Qgm		6-27-55	2.75		D	
60	E3a-2612	William D. Thompson	F. O. Offutt	1955	1117	Drl	6	64	20	Pcol	ss	7-12-55	18.20		D	Fa
61	E3a-2106	Ed Bardelik		1948	1140	Drl		60 r		Qo			35 r		D	
62	E3a-2204	A. Zahnizer			1160	Dug		20 r		Qo			17 r			

63	E3a-2907	L. R. Brown		1952	1100	Drl		30 r		Qgm			20 r		D	
64	E3a-4012	E. Junkin			1100	Dug		25 r		Qal			6 r		D	
65	E3a-4707	James Hartt	F. O. Offutt	1935	1110	Drl	6	65 r	58 r	ℙcol	ss		50 r		D	Fa, La
66	E3a-6713	C. L. Grundy	do.	1947	1060	Drl		40 r		Qo	gr					
67	E3a-8003	Bard Oil Co.		1907	1185	Drl	8	550	84			11-13-56	52.70		O	
68	E3a-8216	R. Baker	F. O. Offutt	1954	1280	Drl	4	105 r	84 r	ℙh	ss		85 r	10 r	D	
69	E3a-7539	Joe Kozakovsky	V. C. Palmer	1955	1375	Drl	6	385	63 r	ℙcou	ss	7-26-55	145.79			Fa
70	E3a-7645	E. Pennman	do.	1955	1282	Drl	8	140	106 r	ℙh	ss	9-15-55	91.20			Fa
71	E3a-0703	Arnold Handkox		1945	1185	Drl	5	85 r	40 r	ℙcl			45 r		D	
379	E3b-6023	Cooper-Bessemer Corp.	Lininger Bros.	1953	1270	Drl	10	297	42 r	Mb		7- 1-53	49.56			T, S
381	E3c-0107	C. W. Yeager			1330	Dug		21.3		Qgm		7- 8-53	2.80		D, S	
383	E3a-7618	F. Offutt	F. O. Offutt		1200	Drl		300	20 r			11-21-56	17.55		O	
386	E3a-7111	Mercer Stone & Mantle Co.	do.	1953	1140	Drl		86		ℙcou		11-13-56	36.86	20 r	O, I	
388	E3a-7922	Paul Alessio			1210	Drl		300	30 r	ℙh	ss	7-28-53	flowing	200		Fa, La
390	E3b-7023	Arc Weld Mfg. Co.			1250	Drl	12	328	160 r	Mb	ss				I	La
514	E3b-6802	Grove City Country Club	Lininger Bros.	1956	1260	Drl	7	52	50 r	Qo	gr		20 r	13 r		
517	E3b-8418	William Jack	William Bonahy	1927	1190	Drl	8	800			s	7- 3-56	flowing			Fa, La
518	E3b-7729	Howard McCoy		1940	1270	Drl	8	872 r	56 r	ℙh	ss	8- 8-56	10.98		A	Fa
519	E3d-1128	William Savolskis			1185	Drl	8					7-31-56	flowing	80	A	
525	E3b-8429	John R. Post			1250	Drl		96 r		ℙh	ss	8- 8-56	29.96		O	Fa, La
526	E3b-8430				1255	Drl	8	582	65	ℙh	ss	8- 8-56	15.54		O	Fa, La, T
527	E3d-2721	Paul Dierker		1936	1245	Drl		94 r	20 r	ℙh	ss	8-15-56	25.90		D, S	Fa, La
528	E3d-2721	do.			1245	Dug		22		Qgm		8-15-56	3.67			Fa
529	E3d-2104	G. H. Seth			1240	Dug		13.6		Qgm		8-15-56	3.92		D, S	Fa
530	E3d-1605	J. A. Small			1265	Dug		18 r		Qo		8-15-56	11.92			Fa
531	E3d-2109	B. F. Wray	Davis & Sons	1955	1270	Drl	6	65 r	50 r	ℙcn			18 r	30 r	D	Fa

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
MERCER COUNTY—Continued																
Mr- 532	E3d-2214	Frank Spanglehour	U. S. Dean	1948	1290	Drl	6	84 r	50 r	Ph	ss	8-22-56	30.16			Fa, La
533	E3d-1516	John Nicoletto	Bowie Coal Co.	1951	1280	Drl	5	35 r	30 r	Pkl	sh		15 r		D, S	Fa
534	E3d-1611	Robert Ferry	F. O. Offutt	1953	1270	Drl	6	38 r	36 r	Pkl	sh				D	Fa
536	E3d-0805	P. Williamson	do.	1936	1250	Drl	6	102 r	76 r	Ph			32 r		D	Fa
537	E3d-0504	Norman C. Dunlap	H. I. Mong	1950	1230	Drl		152 r	152 r	Qo			5 r			Fa
538	E3d-0504	Freedman			1245	Drl						8-23-56	flowing			Fa, La
539	E3a-8560	John A. Briggs	F. O. Offutt	1941	1230	Drl	6	58 r	58 r	Qgm	gr	8-23-56	flowing		D	Fa, La
541	E3c-0258	Blair McLane			1230	Drl	8	150 r				8-23-56	3.27		O, D, S	Fa, La
542	E3c-1461	Harry Keister			1230	Drl	8	81.5	70	Ph	ss	8-23-56	4.33		O	
543	E3c-0553	Leonard Wray	F. O. Offutt		1250	Drl		75 r	50 r	Ph	sh				D	Fa
544	E3c-0553	do.			1250	Dug	36	8.5		Qal		9- 8-56	2.87			Fa
545	E3c-0651	N. O. Welton	F. O. Offutt		1285	Drl	6	75 r	60 r	Pcou	sh	9- 8-56	34.50	25 r	D, S	Fa, La, T
546	E3a-8253	Mrs. Rebecca Decker	do.	1951	1285	Drl	5	112 r	93 r	Ph	ss	9- 8-56	54.37		O, D	Fa, La, T
547	E3a-7753	E. P. Weber	do.	1942	1260	Drl		70 r		Ph	ss				D	Fa
548	E3a-7658	Richard McClure			1245	Dug	36	17.5		Qo		9- 8-56	8.96		O, D	Fa
549	E3a-8061	E. McMichael	F. O. Offutt	1951	1245	Drl	6	73 r	73 r	Qem	gr		15 r		D	Fa
550	E3b-8104	Gilford Wheeler			1230	Drl	3	46		Qem		9- 8-56	flowing		O, D	Fa, La, T
551	E3b-8428	John Kretter		1940	1285	Drl	6	95 r	95 r	Ph	ss		34 r		D	Fa

552	E3a-7557	Alvin Vance	F. O. Offutt		1240	Drl	6	83 r	83 r	Qo	gr	9-10-56	7.25		O	Fa, La
554	E3d-1111	John Bingham, Jr.			1260	Dug	30	17.8		Qem		9-10-56	7.00			Fa
555	E3b-7803	C. F. Pearson			1245	Drl	6	70 r	70 r	Ph	ss	9-10-56	11.77		D, S	Fa
556	E3b-7803	do.			1245	Dug		19.6		Qem		9-10-56	6.37		O, D	Fa
557	E3b-7608	A. B. Buchanan			1225	Dug	30	6.2		Qo		9-10-56	2.4		O	Fa
558	E3b-7010	Donald E. Say	F. O. Offutt	1950	1230	Drl	6	40 r	40 r	Qo	s	9-10-56	4.93			Fa
559	E3b-7312	Mrs. Madden	H. I. Mong	1950	1240	Drl		100 r		Qo	s, gr		0.5 r			Fa
560	E3b-7714	C. L. Riddle			1230	Dug	30	11		Qo	gr	9-10-56	7.27		O	Fa
561	E3b-7912	Earnest Hassell			1235	Dug		14 r		Qo					D	Fa
562	E3a-8462	Robert Fisher	F. O. Offutt	1953	1240	Drl	5	115 r	112 r	Qem	gr		8 r			Fa
563	E3a-2218	Charles Heck, Jr.			1300	Drl	6	95 r		Ph	ss	9-12-56	24.25		O, D	
564	E3d-1523	William Uber			1280	Drl	6	32.8		Qem		9-11-56	20.32		O, D, S	Fa, T
565	E3d-0728	Kenneth Beatty		1948	1230	Drl	6	87 r	72 r	Ph	ss		27 r		D	Fa
566	E3d-0224	L. S. Gragg	F. O. Offutt	1945	1250	Drl	6	80 r	75 r	Ph	ss		40 r		D, S	Fa
567	E3b-7620	C. W. McIntre			1250	Dug	24	20 r		Qo		9-11-56	6.60		O, D	Fa
568	E3b-7620	do.			1270	Drl	4	42.5		Qo		9-11-56	22.98		O	
569	E3b-7619	F. C. Styers	Riddel		1260	Drl	5	120 r	92 r	Pm	sh	9-11-56	9.90		O, D	Fa, La
570	E3b-6513	Roy Mong	H. I. Mong	1948	1245	Drl		75 r		Qo			15 r		D	Fa
571	E3b-6612	Paul L. Rhoads	P. L. Rhoads		1240	Drn	1	15 r		Qal			7. r			Fa
572	E3b-8107	F. N. McDowell	Heasley		1225	Drl	6	26	26 r	Qem		9-11-56	11.68			Fa
573	E3b-7107	Howard Mundt	F. O. Offutt		1280	Drl	6	84 r		Ph	ss	9-12-56	26.70	8 r		Fa
574	E3a-6762	George Smith	John Williamson	1953	1275	Drl		40 r	40 r	Qo				10 r	D	Fa
575	E3a-7549	T. H. Throckmartin			1310	Drl	6	96 r		Ph			60 r			Fa
576	E3a-8145	N. R. Hassell			1300	Drl	5	86 r		Ph			30 r			Fa
577	E3c-0447	G. R. Magee	F. O. Offutt	1938	1340	Drl	6	157 r	72 r	Ph	ss		104 r			Fa
578	E3c-0447	do.			1340	Dug		20		Qem		9-12-56	10.20			Fa, La

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
MERCER COUNTY—Continued																
Mr- 579	E3c-0240	John M. Carr	Parshall Bros.		1360	Drl		180 r		Ph		9-12-56	65.36		O, D, S	Fa
580	E3c-0240	do.			1360	Dug	24	22	22 r	Qem		9-12-56	6.82		O, D, S	Fa
581	E3c-0437	Meade McCracken	Parshall Bros.	1915	1330	Drl		166 r		Ph			65 r		D, S	Fa
582	E3c-0537	C. W. McCracken	Francis McCullough	1955	1330	Drl	8	65 r	40 r	Pkl	ss		25 r		D	Fa
583	E3a-8441	James G. Jones	Talaos	1954	1340	Drl		80 r		Qem					S	Fa
584	E3a-8037	Carl Plummer			1380	Dug		25 r		Qem					D	Fa
585	E3a-8233	Robert Jenny			1375	Dug		32		Qo		9-13-56	12.70		D	Fa
586	E3a-8233	do.		1933	1380	Drl	4	260 r	200 r	Ph	ss		60 r		S	Fa
587	E3c-0133	Elijah Wallace	F. O. Offutt	1955	1320	Drl		100 r	95 r	Pcn	sh		80 r	10 r		Fa
588	E3c-0133	do.			1320	Dug	36	17.9		Qem		9-13-56	6.80			Fa, La, T
589	E3a-7528	A. D. Ramsay	F. O. Offutt	1952	1330	Drl		160 r	160 r	Qo	s		98 r		D	Fa
590	E3a-7524	Dale Hawthorne			1270	Drl	6	100 r	80 r	Ph	ss				D	Fa
591	E3a-7924	Paul Alessio			1240	Drl		65 r		Ph	ss				D	Fa
592	E3a-8528	Clyde Grundy			1250	Drl	5	61		Ph	ss	9-13-56	22.50		D	Fa
593	E3a-8130	Frank Garber			1320	Dug	24	29.3	20 r	Qo		9-18-56	8.32		D	Fa
594	E3a-7718	Robert Welton	Robert Ralston	1949	1220	Drl	5	86 r	20 r	Ph	ss	9-18-56	46.39			
595	E3a-7821	Riley Cameron			1210	Drl		452	80			9-18-56	flowing			Fa, La

597	E3c-0121	Bowie Coal Co.	Bowie Coal Co.		1210	Drl	4	32 r	32 r	Qal		9-19-56	7.80		O, S	Fa
598	E3c-0423	Robert Moors	F. O. Offutt		1240	Drl		38 r		Ph	sh, ss		30 r		D	Fa
599	E3c-0417	John Kopf	V. C. Palmer	1955	1350	Drl	8	165 r	65 r	Pkl Ph	ss		35 r	8 r		Fa
647	E3a-7314	Raymond Hanna	F. O. Offutt	1953	1220	Drl	6	79 r		Ph	ss	9-19-56	41.44		D	Fa
649	E3a-7304	Pauline Edeburn	do.	1949	1070	Drl		48 r		Pco	ss	9-19-56	21.23		O, D	Fa, La
650	E3a-7401	Coryea	do.	1951	1180	Drl		100 r		Pcou	ss				D	Fa
652	E3a-7221	Louis Weber	do.	1939	1300	Drl		119 r		Ph	ss	9-24-56	89.36		O	Fa, La
653	E3a-5739	W. Bobbert	V. C. Palmer	1956	1300	Drl		80 r	58 r	Ph			45 r	20 r		
654	E3a-7523	Clifford Alexander	Deitrich		1280	Drl		117 r		Ph	ss				D	Fa
655	E3a-6522	Mrs. Mildred Thompson	F. O. Offutt		1280	Drl	5	100		Ph	ss					Fa
656	E3a-6921	Clyde Bruck	Ramsay		1280	Drl		140 r		Pcou	ss		80 r			Fa
657	E3a-7215	Earl B. Smith			1140	Drl	6	56.8		Pcol	ss	9-24-56	18.64		O	Fa
658	E3a-6510	T. E. McCracken			1090	Dug	24	15 r		Qal			10 r			Fa
659	E3a-5201	Robert and John Patterson			1250	Dug	24	30.5		Qgm		9-24-56	18.88		O. D	Fa
660	E3a-4301	Raymond A. Woods	F. O. Offutt	1953	1160	Drl	5	59 r	20 r	Pcou	ss	9-24-56	14.21		D	Fa
661	E3a-5216	A. Blumensbine	Ike Coyer		1200	Drl	6	40 r	25 r	Pm						
662	E3a-5517	Robert E. Hume			1240	Drl		114 r		Pcou		9-25-56	73.31		O, D	Fa
663	E3a-5619	Wm. R. Hunt			1100	Dug	24	14		Qo		9-25-56	9.42		O. D	Fa
664	E3a-5627	W. I. Blake			1210	Dug	20	12.8		Qo		9-25-56	7.26		O. D. S	Fa
665	E3a-7130	Dave Baker		1910	1380	Drl	5	206 r		Ph	ss				D. S	Fa
666	E3a-6734	John Koren	F. O. Offutt	1945	1380	Drl		138 r	110 r	Pcn	sh		90 r		D	Fa
667	E3a-6129	R. T. Riffle			1300	Dug	24	30 r		Qo			10.00			Fa
668	E3a-6226	Harry Frisk		1900	1310	Drl	5	117 r		Ph	ss		82 r			Fa
669	E3a-6541	John Barnes			1290	Drl		69 r		Ph	ss		60 r			Fa
670	E3a-6348	Mrs. W. F. White	F. O. Offutt	1944	1300	Drl		105 r		Ph	ss		60 r		D	Fa

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
MERCER COUNTY—Continued																
Mr- 671	E3a-6348	Mrs. F. W. White		1926	1295	Drl	5	98 r		ℙh	ss				S	Fa
672	E3a-7251	George Gilson	F. O. Offutt		1270	Drl		110 r	100 r	ℙh	ss				D, S	Fa
673	E3a-6646	John Welton			1290	Drl		76 r		ℙh	ss		16 r		D	Fa
674	E3a-6650	Donald McCartney			1280	Drl		100 r		ℙh	ss				D	Fa
675	E3a-6354	I. E. Coyer	B. C. Griffith	1955	1340	Drl		300					225 r			Fa
676	E3a-6354	J. Elliott			1335	Drl	6	200 r				10-16-56	71 06		O, D	Fa, La
677	E3b-6304	Essington B. Moon	F. O. Offutt	1948	1270	Drl	6	69 r	32 r	ℙh	ss	10-16-56	27.50		O	Fa, La, T
678	E3b-6000	Orville A. Kaufman			1375	Drl		180 r		ℙcou	ss		150 r		D	Fa
679	E3b-5600	Mrs. J. E. Courtney			1305	Drl		60 r		ℙcn					D	Fa
680	E3a-5654	J. D. Winder			1320	Drl		85 r		ℙh	ss				D	Fa
681	E3a-5051	George Reichel			1340	Dug	60	21.2		Qem		10-16-56	5.83		O, S	Fa
682	E3a-4554	C. L. Masson			1300	Drl	6	60 r		Qem		10-16-56	26.80		O	Fa, La,
683	E3a-4960	Bashline & Rossman Farm	F. O. Offutt		1340	Drl		309 r		ℙco			70 r		D, S	Fa
684	E3a-4062	H. H. McFadden			1350	Drl		115 r		ℙh	ss	10-17-56	62.35		O, D	Fa, La, T
685	E3a-5361	David Hughes				Dug	18	11.2		Qem		10-17-56	5.32		O, D	Fa
686	E3a-5461	Franklin Richardson			1300	Drl	7	93 r	90 r	ℙh	ss		20 r		D, S	Fa
687	E3a-4447	Norman Shipton	V. C. Palmer	1956	1260	Drl	7	31.8	22 r	ℙh	ss	10-17-56	14.94		O, D	
688	E3a-4332	Hayes Junior Thompson			1215	Drl	8	56.0				10-17-56	7.51		O, D	Fa

689	E3a-4724	Clifford Gregg	F. O. Offutt	1925	1280	Drl	5	88.6		ℙh	ss	10-17-56	62.60		O, D	Fa
690	E3a-3927	Mrs. Erma Crill			1205	Drn	2			Qem		10-17-56	flowing	5	D	Fa, La
691	E3a-3419	Ruth Fox	F. O. Offutt	1953	1250	Drl	6	92 r	36 r	ℙcou	ss		36 r	6 r	D	Fa
692	E3a-3817	Andy Bochy			1165	**Drl**		28 r		ℙcou	ss		20 r		D	Fa
693	E3a-4928	L. G. Pearson			1290	Dug		20 r		Qgm			10 r		D, O	Fa
694	E3a-4928	do.	F. O. Offutt		1290	Drl		74 r		ℙh	ss		60 r		S	Fa
695	E3a-4004	Edgar Ramsay			1110	Drl	5	41		ℙcol	ss	10-18-56	10.55		O, D	Fa
696	E3a-3304	Wayne Williams			1110	Dug		20 r		Qo					D	Fa
697	E3a-0205	P. D. Love	Parker Bros.	1956	1285	Drl	8	53 r	22 r	ℙh	ss		20 r	30 r	D	
698	E3a-0906	R. M. Harrison	George Foy		1180	Drl	5	72	16 r	ℙcol	ss	10-18-56	23.11		O, D	Fa, La
699	E3a-0611	Leo Caldwell		1955	1270	Drl		60 r		ℙm	sh				D	Fa
700	E3a-0513	John Kloos		1946	1210	Drl		100 r		ℙcol	ss		30 r		D, S	Fa
701	E3a-0414	S. E. MacTaggert			1140	Drl	6	30.4		Qo		10-18-56	12.39		O, D	Fa, T
702	E3a-0916	James D'Angio		1915	1130	Drl	4	100				10-18-56	26.58		O, D	Fa
704	E3a-2614	Walter Anderson	Francis McCullough	1956	1145	Drl	7	41		ℙcol	ss	10-19-56	9.52		D	Fa
705	E3a-1716	W. M. Zimmerman			1097	Drn	2	20 r		Qal	s, gr				D	Fa
706	E3a-1616	Dr. David Vogan	W. G. McDowell	1950	1097	Drl		112 r	**112 r**	Qo	s		2 r	20 r		Fa, La
707	E3a-0824	J. R. Bellefield			1190	Drl	4	37		ℙco		10-19-56	24.02		D	Fa
708	E3a-0825	O. L. Furey			1205	Drl		80 r	20+r	ℙco	ss		45 r			Fa
709	E3a-2016	John Walmsley	McConnell	1955	1130	Drl		42 r		Qo	s, gr		32 r		D	Fa
710	E3a-1528	George Fox			1240	Drl		140 r		ℙco	ss		40 r			Fa
711	E3a-1721	George Hites	George Hites	1956	1230	Drl	4	40.6		ℙcou	ss	10-22-56	25.10	3 r	D	Fa
712	E3a-1821	Bruce Glenn	Davis & Sons		1250	Drl	4	40 r		ℙm	sh	10-22-56	13.75		O, D	Fa
713	E3a-2028	S. R. Nelson			1325	Drl		68 r		ℙh	ss				D	Fa
714	E3a-2034	Charles Sealand			1295	Dug		28 r	28 r	ℙh	ss				D	Fa
715	E3a-2334	Axel Sealand			1325	Drl		80 r		ℙh	ss		30 r		D	Fa

Table 3.—Record of wells—Concluded

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
MERCER COUNTY—Continued																
Mr- 716	E3a-2436	Earl Anderson			1330	Drl	6	72.5		Ph	ss	10-23-56	54.66		O	Fa, La
718	E3a-2247	Russell Buckley			1360	Drl		185 r		Pcou	ss		150 r		D	Fa
719	E3a-1442	C. W. Carlson	W. G. McDowell	1948	1210	Drl	5	58 r	37 r	Pcou	ss		35 r	30 r	D, S	Fa
720	E3a-1441	Michael Sepik	B. C. Griffin	1955	1180	Drl		40 r	35 r	Pcou	ss					Fa
721	E3a-0744	Roy Carothers			1320	Dug	36	30 r		Qgm			20 r			Fa
722	E3a-0647	D. L. Kimes	H. I. Mong		1180	Drl	6	45 r	27 r	Pcn	sh		10.96		O, D	Fa, La
723	E3a-0663	Paul Patterson	F. O. Offutt	1950	1340	Drl		64 r	43 r	Ph	sh, ss	10-23-56	22.82		S	Fa
724	E3a-0663	do.			1340	Dug		12 r		Pcn	sh		5 r		S	Fa
725	E3a-1458	William Campbell			1230	Dug	36	20.7		Qo		10-24-56	15.39		O, D	Fa
726	E3a-1660	William Lurtz	W. G. McDowell	1948	1230	Drl		94 r	67 r	Pcou	ss		25 r	30 r		Fa
727	E3a-3051	Theodore Davis			1410	Drl		200 r					60 r		S	Fa
728	E3a-3749	Herbert Rowe	Joseph Zimmerman		1360	Drl		160 r		Ph			80 r		D	Fa
729	E3a-3560	J. Miles	F. O. Offutt	1944	1305	Drl		83 r		Ph	ss		30 r		D, S	Fa
730	E3a-2765	Clair Dyer, Jr.	H. I. Mong	1956	1200	Drl	6	81 r	79 r	Qem	gr		6 r	30 r	D	Fa
731	E3a-2157	Charles Campbell	Findley Sirenia		1210	Drl	5	67.3		Pcou	ss	10-24-56	18.61		O, D	Fa, T
732	E3b-1007	Joe Rivers			1400	Drl	6	95 r		Pcn			13 r		D	Fa
733	E3b-1604	Jesse Thompson	B. C. Griffin		1375	Drl	6	89 r	78 r	Ph	ss	10-24-56	56.85		O, D	Fa
734	E3b-1907	Harry Wilson			1365	Drl	5	100 r		Ph	ss		60 r		D, S	Fa

735	E3a-3853	J. W. Reed	H. I. Mong	1952	1380	Drl	6	122 r	55 r	Ph	ss	10-25-56	79.67		O	La, Fa, T
736	E3b-2018	Harry Wilson	Gibbs and Mong		1295	Drl	8	88		Pcou	ss	10-25-56	20.77			
737	E3b-4200	Edward Knouff		1948	1290	Drl		26.6		Qo	s, gr	10-25-56	7.52		O	Fa
738	E3b-3902	J. Miller			1300	Drl		60 r	60 r	Qo	s		58 r		D	Fa
739	E3b-4400	W. W. Richardson	F. O. Offutt		1320	Drl		69 r		Ph	ss		30 r		O	
740	E3b-4401	do.	do.		1305	Drl		27 r		Qo	gr		3 r		D, S	Fa
741	E3b-2703	Marion Pattit			1270	Dug	8	9		Qem		10-25-56	5.84		O, D	Fa
742	E3a-1963	George Sagula			1260	Drl		40 r		Qo	s, gr		20 r	12 r	S, D	Fa
743	E3b-3706	L. F. McDowell			1310	Drl	5	52 r		Qo			48 r			Fa
744	E3b-4309	Chester Gayne	V. C. Palmer		1280	Drl		47 r		Qo	s, gr		20 r		D	Fa
746	E3b-5419	Donald Royle			1260	Dug		16 r		Qo	s		12 r			Fa
747	E3b-5116	James Neyman			1285	Drl		130 r		Pcou	ss				D	Fa
748	E3b-4613	Mrs. J. E. Stone			1285	Drl		70 r		Qo					D	Fa
749	E3b-5608	George Jr. Republic School	F. O. Offutt	1950	1290	Drl	8			Pco	ss, sh		60 r		Ps	Fa
750	E3b-5608	do.	do.		1290	Drl	6	293 r	118 r	Pco	ss, sh				Ps	Fa
751	E3b-5110	do.	Lininger Bros.	1954	1280	Drl		80 r		Qo	gr				D	Fa
752	E3b-5321	H. E. Montgomery	B. C. Griffin	1953	1250	Drl	5	122 r		Qo		10-26-56	16.73		O, D	Fa, T
753	E3b-4616	Frank Gasper	James Thornbury		1320	Drl		100 r	100 r	Pm	sh		60 r		D	Fa
754	E3b-3722	Mrs. Clarence Filer	H. I. Mong	1948	1300	Drl	6	38 r		Qem	s, gr		7 r		D	Fa
755	E3b-3719	Earl Filer			1300	Dug	18	18.6		Qem		10-27-56	14.90		D	Fa
756	E3b-3510	Clyde M. Urey			1320	Drl		70 r		Qem					D	Fa
757	E3b-3511	Harold Bonacker	William Zimmerman		1325	Drl		81.5		Ph	ss	10-27-56	68.22		O, D	Fa
758	E3b-2720	James W. Brown			1320	Drl		80 r	80 r	Qem	s, gr		78 r		D, S	Fa
759	E3b-3524	Howard Brest	Burdett		1265	Drl		61 r	61 r	Qem	gr	10-27-56	flowing		D	Fa, La
760	E3b 3121	Floyd Bell	F. O. Offutt	1928	1360	Drl		90 r		Qem	s, gr				D, S	Fa
761	E3b-3325	Brenton Holter	W. G. McDowell		1265	Drl	5	33.7	40 r	Qem	s	10-27-56	9.26		O, D	Fa, T

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
MERCER COUNTY—Continued																
Mr- 762	E3b-2325	Wendall Coulter	F. O. Offutt		1330	Drl		90 r		₽h	ss		20 r		S, D	Fa
763	E3b-1319	D. F. Coulter	do.	1946	1360	Drl	5	96 r		₽h	ss		39 r		D	Fa
764	E3b-1416	R. J. Hodgson			1350	Drl	6	170 r	100 r	₽h ₽cou	coal ss, sh		80 r		D, S	Fa
765	E3b-0609	Alvin Roberts	F. O. Offutt	1937	1373	Drl		90 r	80 r	₽h	ss		70 r		S	Fa
766	E3b-0017	F. M. Bohlender			1305	Drl		95 r	60 r	₽co			1 r		D	Fa
768	E3b-0233	Mary Hardesty			1300	Drl	4	80 r		Qem	s					
769	E3b-1433	C. J. Donaldson		1940	1285	Drl	4	66 r		Qem		10-29-56	flowing	1	S, D	Fa, La
770	E3b-0441	J. W. Platt	F. O. Offutt	1951	1400	Drl		110 r	20 r	₽co	ss		80 r		S, D	Fa
771	E3b-1741	Robert McCoy	James Thornbury	1949	1290	Drl	6	150 r	150 r	Qem			flowing		D	Fa
772	E3b-1933	D. G. Baker	F. O. Offutt	1919	1300	Drl		68 r	54 r	₽co	ss		12 r		D	Fa
773	E3b-2132	C. B. Montgomery	Erb		1270	Drl	5	100 r	99.5 r	₽co		10-29-56	flowing		D, S	Fa, La
774	E3b-0826	Henry E. Klotz			1295	Drl		1200 r				10-30-56	flowing	500 r	D, S	Fa, La
775	E3b-0255	L. C. Atwell			1370	Dug		22 r		Qem			16 r		D	
776	E3b-0654	H. E. O'Dell			1470	Drl	5	38.5		₽h	ss	10-30-56	17.28		O, D	Fa, T
777	E3h-1351	Floyd Coulter		1885	1390	Dug	30	35.3		₽h	ss	10-30-56	21.34		O	Fa, La
778	E3b-2029	D. G. Grace			1290	Drl	5	41 r	41 r	Qem	gr		12 r		D	Fa
779	E3b-2129	R. P. Braham	F. O. Offutt	1935	1290	Drl		92 r	91 r	₽co	ss		14 r		S	Fa
780	E3b-2129	do.	H. I. Mong	1951	1290	Drl		57 r		Qem	s, gr		13 r		D	Fa

781	E3b-2141	**W. T. Montgomery**	do.	1932	1325	**Drl**		90 r	50 r	₽cou	ss		50 r		**D**	**Fa**
782	E3b-2140	do.		1915	1320	**Drl**		300 r		₽co			50 r		**S**	**Fa**
783	E3b-2259	**Lawrence Whitehouse**	**H. I. Mong**	1946	1320	**Drl**	5	50 r		Qem		10-30-56	flowing		**D**	**Fa, La**
784	E3b-2149	**Homer Elder**			1330	**Drl**	6	85 r	65 r	Qem			20 r		**D, S**	**Fa**
785	E3b-4262	**George W. Lester**			1440	**Dug**		30		Qgm		10-31-56	21.63		**O, D**	**Fa, La**
786	E3b-3156	**H. M. Riddle**		1946	1350	**Drl**	5	84 r		₽h	ss	10-31-56	32.80		**O, D**	**Fa**
787	E3b-3049	**B. E. Wolfe**			1330	**Drl**		167 r		₽co					**D, S**	**Fa**
788	E3b-3648	**C. L. Vanvorth**	**F. O. Offutt**		1345	**Drl**	6	50 r		₽cn					**D**	**Fa**
789	E3b-2888	**Lawrence Whitehouse**	**B. C. Griffin**	1956	1280	**Drl**	4	71.1	70 r	₽cou	ss	10-31-56	19.19		**O, D**	
790	E3b-4344	**R. D. Eperthener**			1280	**Drl**	4	103 r		₽co		10-31-56	21.38		**O, D**	
791	E3b-4934	**John Deitrick**			1290	**Drl**	4			₽h	ss	10-31-56	9.02		**O, D**	**Fa, T**
792	E3b-3729	**Neal Symans**	**Griffin & Burnett**		1265	**Drl**	5	96	90 r	₽cou	ss		20 r		**D**	**Fa**
793	E3b-3632	**A. J. Palmer**	**H. I. Mong**	1953	1260	**Drl**	5	140 r	140 r	₽col	ss	10-31-56	0.64		**O**	**Fa**
794	E3b-3625	**R. L. Whitehall**			1250	**Drl**		60 r		Qal			flowing		**D**	**Fa, La**
795	E3b-4743	**Henry Garrett**			1315	**Drl**	6	101		₽h	ss	11- 1-56	29.09		**O, S**	**Fa, T**
796	E3b-4729	**W. V. McNeish**	**H. I. Mong**		1270	**Drl**	6	73 r	62 r	₽m			30 r		**D, S**	**Fa**
797	E3b-5831	**Edward Hummel**	**J. E. Williams**		1340	**Drl**	6	96 r	78 r	₽cn			61 r			**Fa**
798	E3b-5940	**E. S. Bollender**	**Bowie Coal Co.**		1300	**Drl**	5	19	24 r	Qem	gr	11- 1-56	7.24		**D**	**Fa**
799	E3b-5053	**Wade Miller**			1325	**Drl**	7	90		₽h	ss	11- 1-56	30.27		**O**	
800	E3b-4663	**Clover Crest Dairy**			1400	**Drl**	3	30 r		₽kl			10 r		**S**	**Fa**
801	E3b-5747	**Frank McConnell**	**F. O. Offutt**		1360	**Drl**	5	110		₽cn	ss	11- 2-56	41.92	**8 r**		
802	E3b-6547	**A. C. Wilson**			1280	**Dug**		10 r		Qal			8 r		**D**	
803	E3b-6158	**John McFadden**			1350	**Dug**	36	37.5		Qem	s	11- 2-56	18.00		**O**	
804	E3b-6950	**C. B. Brown**	**H. I. Mong**	1955	1330	**Drl**	5	58 r	20 r	₽cn					**D**	**Fa**
805	E3b-7139	**Lawrence Thompson**	**Lawrence Thompson**	1956	1260	**Drl**	6	32.4		₽cn	ss	11- 2-56	15.98		**O, D**	**La, T**
806	E3b 6437	**G. B. McDougall**			1285	**Drl**		70 r	70 r	₽h	ss					

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
							MERCER COUNTY—Continued									
Mr- 807	E3b-7810	E. Hassell	Vogt		1220	Drl	8	200 r				11-15-56	flowing	100 r	S	Fa, La
808	E3a-4150	Eberly	V. C. Palmer	1956	1310	Drl	7	72 r	38 r	Ᵽh	ss	11-15-56	51.00	20 r	D	
809	E3b-4948	Carl Potters	B. C. Griffin	1954	1305	Drl	5	51.1	53 r	Ᵽh	ss	11-17-56	22.75	23 r	O	
810	E3b-5747	Frank McConnell			1360	Drl	5	147 r		Ᵽcn	ss	11-19-56	38.75		O	
811	E3b-3719	Filer	V. C. Palmer	1956	1325	Drl	7	64 r	53 r	Ᵽh	ss		35 r		D	Fa
812	E3a-7818	Riley Cameron			1240	Drl	6	186 r		Ᵽcou	ss	12-12-56	62.57		O, D	Fa, T
813	E3b-5222	Gerald Vorrlies	V. C. Palmer	1957	1270	Drl	7	153 r	153 r	Qo		3-21-57	29.10		D	
814	E3b-5222	Clair Jamison	B. C. Griffin	1957	1270	Drl	4	168.5	168.5 r	Ᵽcn	sh					
816	E3a-2305	Clifford Hale	V. C. Palmer	1957	1140	Drl	7	105 r	75 r	Ᵽcol	ss		10 r			
817	E3a-0907	Peter Panella	do.	1957	1180	Drl	7	90 r	26 r	Ᵽcol	ss		30 r	20 r		
819	E3b-7416	Grove City Sewage Plant	do.	1957	1220	Drl	8	150 r	75 r	Ᵽcou	ss	4-10-57	flowing	300		Fa, La
821	E3a-4505	Richard Mills	do.	1957	1120	Drl	7	72 r	39 r	Ᵽcol	ss, sh					Fa
830	E3a-7816	Wilbur Ryder	F. O. Offutt	1957	1300	Drl	6	70 r	39 r	Ᵽkl Ᵽcn	sh, ss		50 r	7 r	D	
831	E3a-7541	C. W. Burk	do.	1957	1360	Drl	6	23 r	23 r	Qem	s, gr		7 r		D	
832	E3b-6406	William King	do.	1957	1265	Drl	6	53 r	28 r	Ᵽh	ss		10 r		D	
833	E3b-7010	Clyde Creveving	V. C. Palmer	1957	1220	Drl	6	40 r	40 r	Qo	s, gr		2 r	10 r	D	
849	E3d-0334	W. Wagner	J. E. Williams	1957	1295	Drl	6	75 r	73 r	Qem	s, gr		35 r		D	

850	E3b-8653	Hugh Faulds	H. I. Mong	1957	1442	Drl	6	65 r	28 r	Ᵽcol	ss	7-11-57	32.24		S	
926	E3a-8708	Anthony Guarneri	U. S. Dean	1957	1330	Drl	6	94 r	30 r	Ᵽkl	ss, sh					
927	E3a-8413	Paul Fyffe	do.	1957	1320	Drl	5	80 r	75 r	Ᵽkl	ss		60 r	15 r	D	
928	E3b-4734	John Deitrick	V. C. Palmer	1	1285	Drl	7	75 r	49 r	Ᵽh	ss	9-23-57	22.32		Ps	
929	E3a-0233	Leroy Haag	do.	1957	1160	Drl	6	150 r	94 r	Mh	sh		38 r	3 r	D	La, Fa
930	E3b-5506	George Jr. Republic School	Lininger Bros.	1957	1290	Drl	8	288 r	168 r	Ᵽco	ss		55 r	45 r	Ps	
936	E3a-1528	George Fox	Parker Bros.	1957	1240	Drl	7	160 r	27 r	Ᵽco	ss		60 r	15 r	D, S	Fa
944	E3a-1480	Mrs. J. E. Nelson	Daugherty		1178	Drl	8	346	18 r			4-17-58	47.07			
945	E3b-6020	Cooper-Bessemer Corp.	F. O. Offutt		1255	Drl			50	Mb	ss					T, S
946	E3b-6021	do.			1261	Drl				Mb	ss	3-16-58	27.73		I	T, S
947	E3b-6121	Grove City Boro			1240	Drl	12	300 r		Mb	ss	3-16-58	37.50	60 r	Ps	La
948	E3b-6121	do.			1261	Drl	12	300 r	212	Mb	ss	3-16-58	31.20		Ps	T, S
949	E3b-6121	do.			1261	Drl	12	300 r		Mb	ss	3-16-58	30.41		Ps	T, S
950	E3a-4032	J. Bardelick	Humphrey		1200	Drl	8	884 r	310 r			4- 2-58	flowing		A	Fa
951	E3d-0927	John Lindley	L. H. Mfg. Co.	1915	1200	Drl	8	740	484 r				6 r		D	Fa
952	E3d-0830	W. C. Dale	do.	1914	1220	Drl	8	741	468 r							
953	E3a-8358	Spanglehour	F. O. Offutt		1230	Drl	6	65	53 r	Ᵽh	ss	4- 4-58	8.54		D	
954	E3a-8358	do.			1230	Drl	4	62		Qgm	gr	4- 4-58	0.73		S	
955	E3d-1132	Dale-Heirs		1915	1300	Drl	8	1360 r	55 r						A	
961	E3d-1600	F. Myers	Robert Ralston		1234	Drl	6	96 r	83 r	Ᵽh	ss		12 r		D	Fa
962	E3d-1602	Eugene C. Adams	do.		1279	Drl		61 r	24 r	Ᵽcn					D	Fa
985	E3b-0010	W. Patterson	F. O. Offutt	1920	1350	Drl	4	234 r	200 r	Ᵽco	ss		65 r		D	Fa
986	E3a-7859	Richard McClure	do.	1958	1245	Drl	5	131 r	131 r	Qal	s		5 r	5 r	D	
987	E3a-1721	Dave Husband	V. C. Palmer	1958	1210	Drl	7	65 r	21 r	Ᵽco	ss		25 r	18 r		
989	E3d-0130	Charles Crow	do.	1958	1308	Drl	7	48 r	29 r	Ᵽkl	sh		36 r	10 r	D	Fa
990	E3b-5015	Sidney Jelley	do.	1959	1301	Drl	7	92 r	92 r	Ᵽcou	ss		47 r		D	Fa

Table 3.—Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
MERCER COUNTY—Continued																
Mr- 991	E3b-6501	Ralph Shellito	V. C. Palmer	1957	1275	Drl	7	156 r	156 r	Qo	gr		15 r		D	Fa
992	E3b-4900	Harve Hartman	do.	1957	1336	Drl	7	80 r	69 r	Ph	ss		60 r	20 r	D	Fa
993	E3b-7624	John Runk	do.	1958	1300	Drl	7	132 r	120 r	Ph	ss		65 r		D	Fa
994	E3b-5321	Dr. Frank	do.	1957	1262	Drl	7	136 r	136 r	Qo			10 r		D	Fa
995	E3b-3923	Harry Lanigon	do.	1958	1282	Drl	7	65 r	60 r	Ph	ss		23 r	20 r	D	
1077	E3b-0112	W. J. Patterson	do.	1959	1350	Drl	7	70 r	38 r	Ph	ss		35 r		D	
1100	E3b-2151	Jacob DeBence	H. I. Mong		1320	Drl	4	116 r	96 r	Pcou	ss		26 r			
1101	E3b-1751	W. G. Gildersleeve	James Thornbury	1948	1363	Drl	6	28 r	28 r	Qem			17 r		D	
1103	E3b-2248	Foster Moon	H. I. Mong	1956	1300	Drl	4	64 r	58 r	Pcou	ss		8 r			
1104	E3b-2043	K. B. Buckley	do.	1936	1320	Drl	4	62 r	42 r	Pm	sh		20 r		D	
1105	E3b-1743	C. J. Boyd		1943	1315	Drl		70 r	28 r	Pco	ss					
1106	E3b-1143	O. L. McCoy			1280	Drl		35 r	35 r	Qem	gr		15 r			
1110	E3b-0448	Raymond Thompson	H. I. Mong		1356	Drl	4	55 r	20 r	Mh	sh		10 r			
1111	E3b-0030	William Jacobs		1907	1325	Drl	4	100 r	90 r	Mh	sh		31 r			
1112	E3b-0035	George King	Fred Goodwin	1950	1363	Drl	4	42 r	42 r	Qem					D	
1113	E3b-0033	C. M. Davidson	H. I. Mong		1330	Drl	6	57 r	57 r	Qem	s, gr		30 r		D	
1114	E3b-0426	Art Braine	Art Braine		1354	Drl		72 r	65 r	Pcou	ss		47 r		D	

1115	E3b-0131	Mrs. W. Kline		1912	1325	Drl		107 r	100 r	Mh	sh		18 r		A	
1116	E3b-0131	do.		1938	1325	Drl	6	156 r	140 r	Ms	ss		16 r			
1118	E3b-1756	A. T. Davis	James Thornbury		1380	Drl	7	54 r	50 r	Ph	ss		20 r		S	
1119	E3b-1458	Glenn Buckley	do.		1432	Drl	5	28 r	20 r	Ph	ss		6 r		D	
1121	E3b-0041	Alfred Little		1915	1455	Drl	4	120 r	120 r	Pco	ss		80 r		S, D	
1123	E3a-5550	D. C. Reynolds	F. O. Offutt	1953	1380	Drl		175 r	144 r	Ph	ss		135 r	7		
1124	E3a-3558	John Schiestle		1920	1365	Drl	6	90 r		Pcn	sh		60 r		D	
1125	E3a-1923	Chester Pyle	W. G. McDowell	1952	1250	Drl	6	116 r	20 r	Pcou	ss		55 r	8 r	D	
1126	E3a-2723	George Caldwell	V. C. Palmer		1236	Drl	7	40 r	28 r	Ph	ss		10 r		D	
1127	E3b-4018	Paul Walker	do.	1958	1330	Drl	8	150 r	43 r	Pcou	ss		80 r	12 r	D	
1128	E3a-2524	Dick Eperthener	do.		1253	Drl	7	60 r	30 r	Pcou	ss		20 r	12 r	D	
1130	E3b-6158	John McFadden	B. C. Griffin	1958	1355	Drl	7	57 r	56 r	Qem		10-28-58	26.25		D	
1131	E3b-5811	Grove City Boro			1258	Drl	7	299 r	96	Mb	ss				Ps	
1132	E3b-5810	Grove City Boy Scouts	B. C. Griffin		1271	Drl		60 r	41 r	Ph	sh		30 r			
1133	E3a-1665	William A. Richardson	Ralph Grossman	1958	1310	Drl	6	22 r	22 r	Qo	gr		7 r		D	
1135	E3b-6930	Paul Cirillo	Davis & Sons	1958	1347	Drl	6	90 r	61 r	Pv	ls		65 r			
1136	E3b-0033	Rawleigh McClelland	B. C. Griffin	1958	1320	Drl		91 r	91 r	Qem	s		41 r			
1137	E3a-8116	Amoco Station	F. O. Offutt		1305	Drl		72 r	32 r	Pkl Pcn	ss, sh			15 r		
1138	E3a-8116	Leesburg Presbyterian Church	do.		1305	Drl	4	133 r	110 r	Ph	ss		28 r			
1139	E3d-0231	Edward Jacob	J. E. Williams	1957	1310	Drl	6	45 r	31 r	Pkl	ss	9-30-57	13.98	12 r		
1140	E3b-7421	D. W. McIntre, Jr.	do.	1957	1270	Drl	6	34 r	34 r	Qo			6 r		D	Fa
1141	E3a-0502	Donaldson	F. O. Offutt		1224	Drl	6	70 r	44 r	Pcou	ss				D	
1143	E3b-7902	Ralph Kaltenbaugh	V. C. Palmer	1958	1240	Drl	7	43 r	43 r	Qal	gr		6 r	20 r	D	
1144	E3a-7965	Charles Barnes	do.	1959	1240	Drl	7	55 r	44 r	Ph	ss		10 r	10 r	D	
1145	E3b-8411	Clair Rust		1957	1230	Drl	6	118 r	118 r	Qem			2 r		D	

Table 3.--Record of wells--Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer		Static water level		Yield (gpm)	Use	Remarks
										Name	Composition	Date measured	Depth below land surface (feet)			
							MERCER COUNTY—Continued									
Mr-1147	E3b-8315	A. C. Sheets	H. I. Mong		1205	Drl	6	93 r	90 r	ℙcou	ss		flowing	2	D	Fa
1148	E3d-0015	Kenneth E. Robb	B. C. Griffin		1220	Drl	6	60 r	60 r	Qem	gr		3 r		D	
1149	E3d-0212	Frank Walters	V. C. Palmer	1958	1240	Drl	7	92 r	73 r	ℙh	ss		12 r	20 r	D	
1151	E3d-0814	John M. Boyd	F. O. Offutt		1285	Drl		75 r	60 r	ℙcn	sh		40 r	8 r		Fa
1152	E3d-1215	Robert Rust	H. I. Mong		1260	Drl		54 r	38 r	ℙcn	sh, coal		4 r			
1154	E3d-0215	W. J. Beatty	B. C. Griffin		1240	Drl	6	76 r	72 r	Qem	gr		15 r			
1155	E3a-8024	Stanley Cotten	F. O. Offutt	1958	1240	Drl		60 r	60 r	Qo	gr		27 r	10 r		
1156	E3a-7527	Morton Collins	do.	1958	1330	Drl		132 r	132 r	Qo	s, gr		92 r	10 r		
1157	E3b-4620	Leroy Williams	U. S. Dean	1959	1289	Drl	5	60 r	60 r	Qem	gr		25 r	10 r		
1158	E3b-4620	Walter Bestwick	do.	1959	1289	Drl	5	58 r	58 r	Qem			25 r	10 r		
1159	E3b-1427	United Presbyterian Church	Moody Drilling	1959	1329	Drl	6	158 r	114 r	ℙcol	ss		40 r	20 r		
1160	E3a-0834	E. D. Cathcart	Elmer Book	1958	1209	Drl	5	131 r	20 r	ℙcol	ss		45 r	20 r		Fa, La
1161	E3a-3143	Paul McCauslin	Ralph Grossman	1958	1357	Drl	6	91 r	70 r	ℙh	ss	8-13-59	69.50			
1162	E3d-0535	Merle V. McNutt	V. C. Palmer	1959	1318	Drl	7	128 r	108 r	ℙcn	sh		60 r	20 r	D	
1163	E3b-7440	Maximon Machine Co.	Moody Drilling	1957	1297	Drl	6	33 r	32 r	ℙv	ls		20 r	15 r	A	
1164	E3a-3743	James Lean	Parker Bros.	1957	1347	Drl	7	150 r	79 r	ℙm	sh		90 r	15 r		
1165	E3b-5435	Paul Miller	Lininger Bros.	1956	1362	Drl	7	95 r	95 r	Qem	s, gr		flowing			
1166	E3b-4821	R. E. Winger	Moody Drilling	1956	1294	Drl	8	70 r	60 r	ℙm	sh		25 r	13 r		

Mr-1167	E3d-1516	John Nicoletto	Book & Proch	1959	1280	Drl	6	153 r	113 r	Ph	ss		65 r	20 r	D	
1168	E3b-6021	Cooper-Bessemer Corp.			1261	Drl	8	305	116	Mb	ss	4-27-60	40			
1169	E3b-3951	Dunlap			1385	Drl		78							T	
1170	E3a-0741	J. McDowell			1287	Drl		92							T	
1171	E3b-3028	Hovis			1330	Drl		47							T	
1172	E3b-1139	O. L. McCoy			1330	Drl		53							T	
1173	E3b-1119	R. Coulter			1385	Drl		124							T	
1774	E3b-1204	Sabodis			1400	Drl		95							T	
1175	E3a-6533	Rhoads			1345	Drl		95							T	
1176	E3a-0463				1375	Drl		66							T	
1177	E3b-2910				1360	Drl		76							T	
1178	E3a-8441	Wm. Nemo			1330	Drl		216							T	
1180	E3b-2427				1360	Drl		78							T	
118[illegible]	E3a-2935				1370	Drl		1019							A	
1184	E3d-0024	Turner	V. C. Palmer		1390	Drl	7	276	45	Pco	ss	6-60	77		T	T
1185	D3d-7951	Fred Goodwin	do.		1440	Drl	7	204	33						T	
1186	E3d-1033	D. Brenneman			1324	Drl		159							T	
1187	E3d-1133	do.			1330	Drl		166							T	

Table 4.—Chemical analyses of ground water

Aquifer: Qal, **Recent alluvium**; Qgm, **Kent ground moraine**; Qem, **Kent end moraine**; Qo, **Kent outwash**; ₽km, **Kittanning Formation, middle member**; ₽kl, **Kittanning Formation, lower member**; ₽v, **Vanport Limestone**; ₽cn, Clarion Formation; ₽h, **Homewood Formation**; ₽m, Mercer Formation; ₽co, Connoquenessing Formation, undifferentiated; ₽cou, Connoquenessing Formation, upper member; ₽com, Connoquenessing Formation, middle member; ₽col, Connoquenessing Formation, lower member; Mb, Burgoon Sandstone; Mh, Hempfield Shale.
(Results in parts per million except temperature, field hardness, specific conductance, and pH.)

Well	Aquifer	Date of collection	Temperature °F	Silica (SiO_2)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Sum of dissolved solids	Hardness as $CaCO_3$: Laboratory: Calcium-magnesium	Hardness as $CaCO_3$: Laboratory: Non-carbonate	Hardness as $CaCO_3$: Field: Calcium-magnesium (grains per gallon)[1]	Specific conductance (micromhos at 25°C): Laboratory	Specific conductance: Field	pH: Laboratory	pH: Field
											BUTLER COUNTY												
Bt- 13	₽co	8-23-59	—	10	0.00	0.17	47	8.3	7.5	1.8	200	7.5	1.4	0.2	0.2	182	152	0	11	311	325	8.0	7.0
25	₽co	9-15-59	53	13	1.2	.77	77	13	4.2	1.0	222	65	1.2	.1	.0	285	246	64	17	474	470	7.4	7.1
29	₽col	10-16-59	57	7.1	.14	.03	17	3.8	78	3.3	252	4.3	9.2	.2	.0	247	58	0	4	453	450	7.6	7.6
35	₽h	10-27-57	53	9.2	.04	.05	60	7.8	3.6	1.8	178	35	4.0	.1	6.0	215	182	36	11	362	400	7.0	7.0
43	₽m	9-25-59	—	8.6	.80	.17	64	15	4.2	1.5	268	18	1.0	.2	.5	245	221	2	—	427	—	7.0	—
44	—	10-27-57	52	8.4	.10	.02	15	3.5	256	4.8	330	.0	238	.4	.2	689	52	0	3	1,250	1,150	7.7	7.6
52	₽cn	4-17-57	—	18	.14	.17	61	8.0	3.5	1.6	188	38	6.2	.2	1.0	230	185	31	8	382	300	7.8	7.2
65	—	10-27-57	—	9.1	1.7	.12	9.5	2.6	78	2.6	154	.0	53	.2	.4	231	34	0	3	407	300	7.3	6.8
67	₽cou	4-17-57	—	12	4.9	.14	11	7.2	2.5	2.1	23	33	8.4	.2	.3	88	57	38	—	151	220	5.6	6.0
83	₽v	9-24-59	—	7.9	2.3	.15	114	30	5.5	4.3	262	207	3.2	.1	1.3	503	408	194	—	760	—	7.1	—
98	₽kl	10-28-59	53	6.4	11	1.1	40	14	5.0	.8	88	52	29	.1	.4	192	158	86	8	340	400	6.6	6.4
											LAWRENCE COUNTY												
La- 107	₽cn	4-16-57	—	26	0.34	0.02	63	17	3.6	0.9	209	49	12	0.3	0.1	275	227	56	14.	489	475	7.1	6.9
150	—	4-16-57	—	10	.52	.14	31	12	1.8	2.2	138	16	1.8	.2	.0	143	127	14	8	363	340	6.6	7.2
182	—	10-27-57	50	8.6	.28	.02	57	13	31	3.8	270	13	24	.1	1.1	285	196	0	10	501	500	7.4	7.6

493	Pkl	9-24-59	—	17	1.1	.17	73	18	3.5	.5	250	46	7.2	.2	.2	289	256	51	15	501	500	7.7	6.6
533	Pcou	9-24-59	—	6.4	4.1	.05	34	9.4	100	5.0	290	1.2	66	.2	.0	365	124	0	8	652	680	7.6	7.6
638	Pm	9-25-59	—	10	8.5	.77	102	40	7.5	2.5	366	136	3.4	.1	.2	483	419	119	26	760	800	6.7	6.8
663	—	7- 9-58	—	8.7	.52	—	58	13	27	3.7	262	35	8.5	.3	.1	284	199	0	—	484	—	7.5	—
677	Pkl	10-16-59	57	9.4	2.6	.19	102	34	7.5	2.0	402	56	3.0	.1	.4	413	395	65	16	756	700	6.5	6.9
695	Ph	9-24-59	—	14	5.3	.77	18	4.6	3.5	.5	74	8.3	2.4	.1	.2	89	64	4	—	139	—	6.8	—
712	Pkm	10-16-59	57	9.8	3.0	.24	42	13	5.6	1.0	150	37	2.2	.1	.2	185	159	36	6	364	350	6.5	6.7

MERCER COUNTY

Mr- 19	Pcou	4-17-57	—	11	0.00	0.02	35	9.3	1.3	0.8	125	20	3.6	0.2	0.9	144	126	23	—	258	—	7.3	6.6
28	Qem	10-27-57	—	10	1.8	.07	9.5	2.8	3.8	2.0	23	22	5.6	.1	1.4	69	35	16	3	110	115	6.4	5.5
42	Ph	4-16-57	—	20	.18	.02	153	53	4.9	2.2	228	392	5.9	.1	.6	744	600	412	32	1.140	—	6.6	6.6
51	Pcn	4-17-57	—	18	.18	.03	60	15	3.6	1.4	227	11	22	.3	.0	243	211	25	14	435	450	7.5	6.6
57	Ph	4-17-57	—	23	1.8	.07	44	22	4.4	1.1	170	48	24	.1	.1	250	200	61	18	594	650	6.9	7.2
65	Pcol	9-25-59	—	10	1.6	.07	40	8.8	7.5	1.8	168	20	1.6	.1	.0	173	136	0	10	295	320	7.1	7.0
388	Ph	10-26-57	53	18	3.9	.60	210	62	11	2.7	430	396	3.0	.1	.0	915	780	427	37	1,210	1,300	7.1	6.8
390	Mb	7- 8-58	—	7.9	.06	.03	35	7.2	45	5.2	235	13	7.5	.2	2.0	240	121	0	—	482	—	7.7	—
517	—	10-25-57	—	9.8	.20	.05	43	8.5	74	7.6	218	11	84	.1	.0	345	143	0	8	611	600	7.4	7.5
525	Ph	4-17-57	—	16	.98	.19	46	8.7	4.4	.9	193	7.7	1.4	.2	.4	181	151	0	8	308	350	7.3	7.0
526	Ph	6-24-58	—	12	1.3	.36	42	7.8	4.7	1.1	162	5.9	1.5	.2	.4	155	137	4	—	.269	—	7.1	—
527	Ph	4-16-57	—	15	.49	.26	31	19	4.4	1.3	170	19	4.5	.2	.1	178	156	16	13	428	370	7.3	7.4
532	Ph	4-16-57	—	21	.02	.45	31	20	4.2	1.1	177	15	2.4	.2	.0	182	160	14	—	500	425	7.2	7.3
538	—	10-26-57	55	12	3.5	.00	41	10	10	1.9	204	0.0	1.2	.1	.0	176	144	0	8	308	350	8.0	7.6
539	Qgm	4-16-57	—	14	.85	.09	26	15	5.7	2.0	152	15	1.1	3	.0	155	126	2	13	397	425	7.2	7.8
541	—	4-16-57	—	8.6	—	—	19	5.8	5.8	2.0	139	11	1.5	.2	.4	132	109	0	16	409	425	7.8	7.5
545	Pcn	4-16-57	—	10	2.0	.01	37	19	4.9	1.4	212	14	1.5	.3	.4	193	170	0	—	483	—	7.6	7.4

Table 4.—Chemical analyses of ground water—Continued

Well	Aquifer	Date of collection	Temperature °F	Silica (SiO$_2$)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Sum of dissolved solids	Hardness as CaCO$_3$ Laboratory Calcium-magnesium	Hardness as CaCO$_3$ Laboratory Non-carbonate	Hardness as CaCO$_3$ Field Calcium-magnesium (grains per gallon)[1]	Specific conductance (micromhos at 25°C) Laboratory	Specific conductance (micromhos at 25°C) Field	pH Laboratory	pH Field
MERCER COUNTY—Continued																							
Mr- 546	Ph	4-17-57	—	11	5.0	0.91	140	46	7.9	3.4	187	411	2.7	0.3	0.8	715	538	386	33	1,190	1,200	7.0	6.0
550	Qem	10-27-57	55	11	1.5	.22	48	12	3.8	1.6	198	12	1.4	.2	.2	188	170	7	9	325	360	7.4	7.6
552	Qo	4-17-57	—	8.1	.16	.04	32	6.0	18	3.0	68	51	11	.1	35	198	104	49	4	327	300	7.1	6.6
569	Pm	4-17-57	—	7.9	3.9	.27	23	11	14	3.8	169	1.5	1.4	.3	1.1	151	102	0	8	339	350	8.0	7.2
578	Qem	4-16-57	—	18	.05	.09	72	16	12	3.2	156	110	8.3	.2	23	340	246	118	12	534	550	8.1	7.2
588	Qem	4-16-57	—	11	.18	.09	15	4.5	2.8	1.2	16	40	2.0	.4	8.5	93	56	43	—	149	—	6.9	6.4
595	—	10-26-57	53	12	1.4	.17	131	9.0	9.0	3.0	272	221	3.2	.1	.0	538	430	207	24	783	850	7.3	6.8
649	Pco	4-17-57	—	12	11	.82	13	4.0	1.6	1.5	50	12	1.0	.4	.2	81	40	8	—	116	170	6.0	6.6
652	Ph	4-17-57	—	14	1.6	1.1	59	19	4.2	1.0	228	49	4.1	.4	.2	263	225	38	—	542	510	7.7	7.2
676	—	4-17-57	—	10	.70	.22	80	4.6	4.6	2.6	210	133	1.2	.3	.5	358	290	118	19	643	650	7.7	6.6
677[2]	Ph	4-17-57	—	14	.12	.25	46	13	3.4	.7	171	21	2.4	.2	1.8	195	168	15	8	346	375	8.4	7.2
682	Qem	4-16-57	—	14	5.4	1.4	69	18	3.4	1.1	189	111	2.4	.1	.8	313	246	91	—	493	—	8.0	7.1
684	Ph	4-16-57	—	9.0	33	1.4	132	32	3.7	2.5	24	451	1.8	.1	.7	645	461	442	—	882	—	7.0	6.2
690	Qem	10-26-57	52	11	.02	.00	23	5.5	2.0	.8	77	19	2.4	.1	4.1	106	80	17	5	177	106	6.7	6.8
698	Pcol	4-17-57	—	14	.34	.07	25	6.0	3.0	.8	55	36	3.7	.2	15	131	87	42	4	206	220	7.4	5.6
706	Qo	10-26-57	63	6.8	.72	.00	37	9.5	480	49	330	1.5	620	.1	.4	1,370	132	0	6	2,470	2,570	7.4	8.1
716	Ph	4-17-57	—	10	15	.36	51	15	2.8	1.5	88	117	1.7	.2	.3	243	188	116	—	379	400	7.9	6.2
722	Pcom	4-16-57	—	12	23	0.99	15	6.7	4.4	0.7	22	52	5.0	0.4	0.4	107	65	47	—	177	—	7.2	6.6

735	Ph	4-16-57	—	12	.45	.06	47	24	7.7	3.1	274	21	1.2	.2	.7	252	216	0	12	604	—	7.3	7.6
759	Qem	10-25-57	53	9.0	.63	.36	57	15	17	2.2	258	22	4.8	.2	.0	254	204	0	—	437	450	7.4	7.5
769	Qem	10-25-57	54	16	.61	.27	46	14	8.0	1.7	210	10	1.4	.2	.0	200	173	0	9	345	375	7.5	7.4
773	Pco	10-25-57	54	13	.09	.31	49	11	7.5	1.7	208	12	1.8	.2	.0	198	168	0	8	335	375	8.1	6.6
774	—	10-27-57	53	16	.42	.04	47	24	24	3.2	246	9.8	3.6	.1	.1	237	167	0	8	393	440	7.5	7.4
777	Ph	4-16-57	—	11	.81	.29	56	13	8.7	3.3	130	61	3.6	.3	34	255	193	86	14	455	450	7.3	7.6
783	Qem	10-25-57	52	10	1.4	.22	28	7.5	3.5	1.4	122	6.1	1.0	.1	.0	118	101	1	6	206	200	6.6	6.2
785	Qem	4-16-47	—	10	.38	.09	9.8	4.8	5.2	2.0	15	36	5.0	.1	5.1	85	44	32	3	142	150	5.8	5.9
794	Qal	10-25-57	—	15	1.3	.27	62	15	7.5	1.3	256	15	2.6	.2	.0	245	216	6	12	419	440	7.4	7.3
805	Pcn	8-23-58	57	—	—	—	46	11	4.1		132	49	7.0	.0	.2	182	160	52	--	329	—	6.8	—
807	—	10-26-57	53	9.4	—	—	49	22	22	3.1	220	28	6.0	.1	.0	237	168	0	8	417	440	7.6	7.4
819	Pcou	4-18-57	—	10	.80	.36	26	10	20	2.5	168	13	3.4	.2	.0	168	106	0	8	367	395	7.8	7.1
929	Mh	10-16-59	—	6.0	2.2	.15	12	5.2	85	4.3	240	22	7.2	.7	2.1	263	52	0	2	422	450	7.3	7.3
947	Mb	7- 9-58	51	11	1.7	.22	51	11	21	3.0	207	31	10	.3	.8	241	173	3	—	409	—	8.0	—
1160	Pcol	9-24-59	--	9.8	2.9	.19	24	6.6	3.5	1.8	64	38	5.4	11	2.0	123	87	35	8	209	220	6.4	6.3
(3)	Pcn	9-22-59	—	6.9	.04	.13	59	10	3.5	2.8	234	10	1.2	.2	.4	209	188	0	—	367	—	7.8	—

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[1] Grains per gallon may be converted to parts per million by multiplying by 17.12.
[2] 8 parts per million carbonate (CO_3).
[3] Sample from sandstone in coal stripmine at Station 31.

Table 5.—Field analyses of ground water

Recent Alluvium

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr-544	5.4	8	270	9- 8-56
571	6.1	12	. . .	9-11-56
597	6.8	14	430	9-18-56
658	5.6	5	190	9-24-56
705	5.7	7	270	10-19-56
794	7.3	12	440	10-25-57
Kent Ground Moraine				
La-462	7.2	5	280	9-19-56
Mr-528	. .	13	400	8-15-56
528	7.4	. .	. . .	4-15-57
529	6.5	8	220	8-15-56
539	7.8	13	425	8-23-56
659	5.5	6	290	8-24-56
693	5.5	5	230	10-18-56
721	7.1	14	570	10-23-56
755	6.8	15	560	10-27-56
785	6.3	7	260	10-31-56
785	5.9	3	150	4-16-57
Kent End Moraine				
La-473	6.7	9	380	9-20-56
476	6.7	14	500	9-21-56
483	6.8	7	270	12- 6-56
492	7.4	14	460	12-13-56
502	6.2	9	425	5- 8-57
511	7.3	29	1,000	5- 9-57
516	7.4	15	530	5-10-57
517	7.8	12	380	5-10-57
518	6.2	4	190	5-10-57
525	7.8	13	350	5-11-57
528	7.5	12	380	5-11-57
679	7.4	10	295	6- 3-58
720	. .	11	400	6- 4-58
Mr- 21	5.5	3	160	. . . .
28	5.5	3	115	-56
549	5.9	10	360	9- 8-56
550	5.9	10	340	9- 8-56
550	7.6	9	360	10-27-57
554	5.6	14	550	9-10-56
556	5.7	12	450	9-10-56
562	6.1	11	380	9-10-56
564	5.3	6	260	9-11-56

Table 5.—Field analyses of ground water—Continued

Kent End Moraine—Continued

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr-572	6.1	9	350	9-11-56
578	6.0	..	500	9-12-56
578	7.2	12	550	4-16-57
580	5.8	10	370	9-12-56
583	7.2	16	550	9-13-56
584	5.5	8	320	9-13-56
588	5.5	4	150	9-13-56
588	6.4	..	...	4-16-57
681	5.3	5	200	10-16-56
682	7.0	..	520	10-16-56
682	7.1	..	...	4-16-57
685	5.5	5	200	10-17-56
690	5.6	5	170	10-17-56
690	6.8	5	106	10-27-57
730	7.5	14	460	10-25-56
741	6.8	11	550	10-25-56
754	..	3	1,800	10-27-56
756	7.2	18	580	10-27-56
758	7.2	16	500	10-27-56
759	7.2	10	470	10-27-56
759	7.5	..	450	10-25-57
760	7.2	11	370	10-27-56
761	7.6	12	320	10-27-56
769	7.6	10	375	10-29-56
769	7.4	9	375	10-27-57
771	7.4	7	300	10-29-56
775	7.3	15	575	10-30-56
778	7.9	11	360	10-30-56
780	7.7	9	320	10-30-56
783	6.8	6	230	10-30-56
783	6.2	6	200	10-27-57
784	..	4	150	10-30-56
798	..	15	550	11- 1-56

Kent Outwash

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
La-465	6.1	5	260	9-19-56
478	6.1	2	60	9-21-56
482	7.7	10	320	11-27-56
488	5.5	4	260	12-13-56
499	7.6	..	730	5- 8-57
500	7.3	11	610	5- 8-57
501	7.7	7	450	5- 8-57
504	6.7	15	1,000	5- 8-57
523	7.5	15	450	5-11-57
524	7.4	12	370	5-11-57

Table 5.—Field analyses of ground water—Continued

Kent Outwash—Continued

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr- 44	7.5	10	350	....
530	6.1	5	110	8-15-56
537	5.9	9	...	8-22-56
548	5.6	14	435	9- 8-56
552	5.5	8	370	9-10-56
552	6.6	4	300	4-17-57
557	5.6	10	350	9-10-56
558	6.1	13	330	9-10-56
559	6.1	11	350	9-10-56
560	5.5	4	150	9-10-56
561	5.7	10	350	9-10-56
567	5.4	7	290	9-11-56
570	6.1	11	350	9-11-56
574	5.6	19	700	9-12-56
585	5.6	9	370	9-13-56
589	7.6	15	525	9-13-56
593	5.3	5	250	9-18-56
663	5.6	4	170	9-25-56
664	5.3	7	200	9-25-56
667	7.2	9	290	9-25-56
696	5.5	8	320	10-18-56
701	5.8	7	250	10-18-56
706	8.1	9	2,100	10-19-56
706	8.1	6	2,570	10-26-57
709	7.5	9	325	10-22-56
725	5.8	15	500	10-24-56
737	..	4	180	10-25-56
738	..	6	270	10-25-56
740	7.2	13	470	10-25-56
742	7.2	17	550	10-26-56
743	7.7	13	420	10-26-56
744	7.3	13	450	10-26-56
746	7.1	12	450	10-26-56
748	7.4	11	370	10-26-56
751	7.4	12	400	10-26-56
752	7.2	12	400	10-26-56
991	7.2	22	850	9- 8-58
994	7.3	11	325	9- 8-58
1140	7.4	11	475	9-30-57

Kittanning Formation, Middle Member

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Bt- 32	7.5	8	170	6-31-56
42	5.9	18	435	8- 2-56
La-712	6.7	6	350	10-16-59

Table 5.—Field analyses of ground water—Continued

Kittanning Formation, Lower Member

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Bt- 62	6.7	19	470	8-10-56
98	6.4	8	400	10-28-59
La-469	6.1	8	345	9-20-56
477	7.2	14	345	9-21-56
485	5.5	3	120	12-13-56
493	6.6	15	500	4-18-57
494	7.4	22	670	5- 8-57
508	7.3	20	550	5- 9-57
510	7.1	..	530	5- 9-57
514	7.3	21	640	5-10-57
515	7.2	10	450	5-10-57
677	..	15	700	6- 4-58
677	6.9	16	700	10-16-59
744	6.9	17	700	10-27-59
Mr- 12	7.3	9	300	11-14-56
533	5.6	16	...	8-22-56
534	5.7	10	...	8-22-56
582	7.3	20	600	9-12-56
[2]599	5.5	..	725	9-18-56
800	..	3	140	11- 1-56
989	6.8	8	210	8-28-58

Vanport Limestone

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Bt- 48	6.6	7	190	8- 3-56
131	7.1	9	...	9-22-59
La-498	7.5	15	530	5- 8-57
506	7.6	12	525	5- 9-57
532	7.6	16	450	5-15-57

Clarion Formation

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Bt- 52	..	10	325	8- 7-56
52	7.2	8	300	4-17-59
64	6.1	6	140	8-10-56
144	7.0	13	400	9-22-59
145	7.1	7	370	9-22-59
152	7.4	..	350	9-22-59
La- 98	6.4	8	400	11- -59
107	6.9	14	475	4-16-57
472	7.0	14	445	9-20-56
497	7.7	10	410	5- 8-57
737	7.2	13	450	9-23-59
742	7.0	27	850	9-23-59
Mr- 31	7.5	10	345	....

Table 5.—Field analyses of ground water—Continued

Clarion Formation—Continued

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr- 46	5.7	10	490	....
51	7.2	13	440	-56
51	6.6	14	450	4-17-57
531	5.9	15	...	8-22-56
545	5.8	15	470	9- 8-56
545	7.4	..	...	4-16-57
587	5.7	28	850	9-13-56
666	7.2	19	550	9-25-56
679	7.2	19	560	10-16-56
724	6.8	9	300	10-23-56
732	7.3	..	1.150	10-24-56
788	6.9	9	300	10-31-56
797	..	..	610	11- 1-56
804	..	..	300	11- 2-56
962	..	11	410	5- 3-58
1151	7.8	21	650	8-11-59
Homewood Formation				
Bt- 34	7.1	7	190	8- 1-56
35	6.3	8	200	8- 1-56
35	7.0	11	400	10-27-57
51	6.8	10	320	8- 7-56
59	6.6	6	200	8- 9-56
61	7.7	13	...	8-10-56
66	6.5	9	230	8-15-56
135	7.4	9	350	10- -59
141	7.0	5	200	10-27-59
La-464	6.8	6	210	5-19-56
489	6.9	9	345	12-13-56
491	7.1	8	270	12-13-56
513	7.6	7	245	5-10-57
526	6.1	4	200	5-11-57
676	..	13	425	6- 4-58
695	7.1	4	150	9- 8-58
[3]696	6.8	8	375	9- 8-58
Mr- 17	6.8	9	300	....
26	5.7	10	325	....
42	7.0	34	1.060	-56
42	6.6	32	...	4-16-57
48	7.2	47	1.400	....
52	7.1	23	650	....
57	7.2	18	640	-56
57	7.2	18	650	4-17-57
70	7.2	12	420	....

Table 5.—Field analyses of ground water—Continued

Homewood Formation—Continued

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr-388	5.8	41	1,100	9-26-56
388	6.8	37	1,300	10-26-57
518	6.8	10	280	7-30-56
525	6.3	7	250	8- 8-56
525	7.0	8	350	4-17-57
526	7.8	5	170	8- 8-56
527	..	12	375	8-15-56
527	7.4	13	370	4-16-57
532	..	16	...	8-22-56
532	7.3	..	425	4-16-57
536	5.9	15	...	8-22-56
543	6.0	14	420	9- 8-56
546	5.9	14	480	9- 8-56
546	7.0	33	1,050	11-14-56
546	6.0	33	1,200	4-17-57
547	6.0	11	380	9- 8-56
551	5.9	11	340	9- 8-56
555	5.9	11	280	9-10-56
565	6.0	13	395	9-11-56
566	5.9	10	280	9-11-56
573	7.0	11	400	9-12-56
575	7.2	8	350	9-12-56
576	7.2	14	470	9-12-56
577	7.0	20	700	9-12-56
579	7.5	23	750	9-12-56
581	7.2	14	370	9-12-56
586	5.8	45	1,200	9-13-56
590	7.2	12	420	9-13-56
591	7.4	14	500	9-13-56
592	6.0	16	550	9-13-56
598	5.8	7	145	9-18-56
[4]599	5.5	..	725	9-18-56
647	5.5	6	190	9-19-56
652	7.0	17	400	9-24-56
652	7.2	..	510	4-17-57
654	7.4	22	630	9-24-56
655	7.4	11	350	9-24-56
665	7.2	12	375	9-25-56
668	7.2	9	340	9-26-56
669	5.8	5	150	9-26-56
670	7.4	14	400	9-26-56
671	7.2	14	450	9-26-56
672	7.4	15	510	10-16-56
673	7.4	14	440	10-16-56

Table 5.—Field analyses of ground water—Continued

Homewood Formation—Continued

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr-674	7.2	16	510	10-16-56
677	7.2	11	360	10-16-56
677	7.2	8	375	4-17-57
680	7.4	15	480	10-16-56
684	5.7	. .	900	10-17-56
684	6.2	. .	. . .	4-17-57
686	7.3	11	360	10-17-56
689	7.4	11	360	10-17-56
694	7.2	10	270	10-18-56
713	7.2	8	290	10-29-56
714	5.4	6	220	10-22-56
715	5.7	5	180	10-29-56
716	5.8	. .	380	10-23-56
716	6.2	. .	400	4-17-57
723	6.7	30	950	10-23-56
728	7.1	21	650	10-24-56
729	5.5	5	230	10-24-56
733	7.4	19	625	10-24-56
734	7.5	13	430	10-24-56
735	7.2	18	620	10-25-56
735	7.6	12	. . .	4-16-57
757	7.0	17	540	10-27-56
762	6.8	10	300	10-27-56
763	6.8	12	420	10-27-56
[5]764	7.2	11	450	10-29-56
765	7.1	18	600	10-28-56
776	. .	6	200	10-30-56
777	7.1	10	420	10-30-56
777	7.6	14	450	4-16-57
786	5.4	7	300	4-30-57
791	6.8	9	300	10-31-56
795	7.3	10	350	11- 1-56
811	7.1	8	350	12-12-56
961	7.4	12	450	5- 3-58
992	7.4	8	250	8- -58
993	7.5	10	375	8- 8-58

Mercer Formation

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Bt- 43	7.1	15	430	8- 2-56
56	6.5	3	820	8- 8-56
142	7.1	4	400	10-27-57
La-638	6.8	26	800	9- 6-57
[2]696	6.8	8	375	9- 8-58

Table 5.—Field analyses of ground water—Continued

Mercer Formation—Continued

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr- 15	6.9	13	450	....
37	7.2	15	480	....
569	6.0	10	400	9-11-56
569	7.2	8	350	4-17-57
699	7.0	25	900	10-18-56
712	5.8	11	420	10-22-56
753	7.2	16	550	10-26-56
796	..	9	350	11- 1-56
Connoquenessing Formation, Upper Member				
Bt- 38	7.2	8	390	8- 2-56
46	6.9	12	290	8- 3-56
49	6.7	10	285	8- 7-56
67	6.0	3	110	8-15-56
67	6.0	.	220	4-17-57
104	7.0	10	450	10- -59
La-481	7.7	9	300	12- 6-56
490	7.4	10	350	12-13-56
520	7.5	11	430	5-10-57
533	7.6	8	680	9-24-59
732	7.6	17	475	9-19-59
Mr- 19	6.6	10	350	4-17-57
69	7.3	10	450	....
650	5.6	3	50	9-19-56
656	7.2	12	360	9-24-56
660	7.2	10	310	9-24-56
662	5.6	6	210	9-25-56
678	7.5	11	340	10-16-56
691	7.0	11	340	10-17-56
692	6.8	8	270	10-17-56
711	5.6	4	135	10-22-56
718	7.3	9	450	10-23-56
719	7.5	13	450	10-23-56
720	5.7	..	1,200	10-23-56
726	7.3	12	440	10-24-56
731	7.2	22	780	10-24-56
747	7.2	11	390	10-26-56
[2]764	7.2	11	450	10-29-56
781	5.7	4	165	10-30-56
792	..	8	300	10-31-56
812	7.0	9	360	12-12-56
819	7.1	9	395	4-18-57
990	7.3	19	470	8-28-58
1147	7.6	12	370	8-11-59

Table 5.—Field analyses of ground water—Continued

Connoquenessing Formation, Middle Member

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Mr-722	5.7	5	270	10-23-56
722	6.6	..	...	4-16-57
Connoquenessing Formation, Lower Member				
Bt- 29	7.6	4	450	10-16-59
La-474	6.8	6	215	9-20-56
Mr- 60	6.8	8	290	....
65	7.0	10	320	9-25-59
657	7.2	10	310	9-24-56
695	5.5	3	130	10-18-56
698	5.6	6	160	10-18-56
698	5.6	4	220	4-17-57
700	6.9	11	360	10-18-56
704	7.5	6	220	10-18-56
793	..	10	360	10-31-56
821	6.3	4	200	5- 7-57
1160	6.3	8	220	8-13-59
Connoquenessing Formation, Undifferentiated				
Bt- 13	7.0	11	325	9-30-59
25	7.1	17	470	6- 9-60
Mr-649	5.5	..	100	9-19-56
649	6.6	..	170	4-17-57
683	6.8	21	580	10-17-56
707	5.6	7	170	10-19-56
708	5.9	9	290	10-19-56
710	..	7	250	10-22-56
749	7.1	8	330	10-26-56
750	7.1	8	330	10-26-56
766	7.4	11	380	10-29-56
770	6.9	7	240	10-29-56
772	7.0	7	270	10-29-56
773	7.1	10	360	10-29-56
773	6.6	8	375	10-25-57
779	7.3	10	350	10-30-56
782	7.0	7	270	10-30-56
787	7.1	10	350	10-31-56
936	7.8	..	300	1- -59
985	6.5	16	500	8-30-58
Hempfield Shale				
Mr-929	7.3	2	450	10-16-59

Table 5.—Field analyses of ground water—Concluded

Unidentified

Well Number	pH	Hardness (in grains per gallon)[1]	Specific conductance (micromhos at 25°C)	Date of collection
Bt- 36	6.7	16	390	8- 1-56
39	6.7	13	350	8- 2-56
44	7.0	3	800	8- 2-56
44	7.6	3	1,150	10-31-57
45	6.3	9	230	8- 3-56
65	6.8	3	300	8-15-56
La-150	7.2	8	340	4-16-57
182	7.6	10	500	10-27-57
428	6.1	10	310	10- -59
480	7.1	11	380	12- 8-56
484	5.7	5	200	12-13-56
486	5.5	4	175	12-13-56
505	8.0	7	280	5- 8-56
507	7.6	11	425	5- 9-57
512	7.4	24	780	5- 9-57
518	7.4	15	420	5-10-57
522	7.2	12	390	5-10-57
529	8.0	10	400	5-11-57
530	7.5	13	380	5-14-57
531	7.5	9	310	5-14-57
La-723	6.4	6	170	9-19-58
Mr-517	6.9	10	400	7-30-56
517	7.5	8	600	10-25-57
538	6.0	9	340	8-23-56
538	7.6	8	350	10-26-57
541	7.5	15	485	4-16-57
541	..	14	430	8-11-58
595	7.2	24	650	9-18-56
595	6.8	24	850	10-26-57
675	7.2	20	660	10-16-56
676	7.2	22	580	10-16-56
676	6.6	19	650	4-17-57
688	7.5	16	510	10-17-56
702	7.9	9	400	10-18-56
727	7.4	17	580	10-24-56
774	7.4	10	430	10-30-56
774	7.4	8	440	10-27-57
807	7.3	11	380	11-15-56
807	7.4	8	440	10-26-57
950	7.1	22	1,500	4- 2-58
951	7.7	6	500	4- 3-58

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[1] Grains per gallon may be converted to parts per million by multiplying grains per gallon by 17.12.

[2] Aquifer uncertain, may be the Homewood Formation.

[3] Aquifer uncertain, may be the Mercer Formation.

[4] Aquifer uncertain, may be the lower member of the Kittanning Formation.

[5] Aquifer uncertain, may be the upper member of the Connoquenessing Formation.

Table 6.—Sample logs of wells

Sample log of well Bt-17

Samples described by: W. S. Lytle
Correlation by: C. W. Poth

Description	Thickness in feet	Depth in feet
Quaternary System		
Illinoian Till		
Sand and gravel, coarse, pebbles consist mostly of sandstone.	5	5
Pennsylvania System		
Kittanning Formation, middle member		
Sandstone, brownish-gray, very fine- to fine-grained; considerable interbedded grayish-black carbonaceous shale containing some muscovite.	11	16
Claystone, gray, minute fragments of carbonized plant remains; interbedded very fine-grained gray sandstone at 24 to 26 feet.	14	30
Shale, grayish-black, containing a little muscovite and abundant pyrite.	2	32
Claystone, gray, containing abundant muscovite and a few minute fragments of carbonized plant remains.	12	44
Sample missing.	2	46
Kittanning Formation, lower member		
Coal, containing a little pyrite.	4	50
Claystone, light-gray, sandy, containing a little muscovite and abundant siderite nodules at 59-61 feet; considerable interbedded light-gray shale.	11	61
Sandstone, light-gray, very fine-grained, silty, containing abundant siderite nodules.	6	67
Claystone, greenish-gray, containing abundant siderite nodules; considerable interbedded light-gray shale.	3	70
Vanport Limestone		
Limestone, grayish-brown, very fine, dense.	20	90
Clarion Formation		
Coal, Scrubgrass.	1	91
Sandstone, gray, very fine- to fine-grained, silty, containing muscovite and pyrite.	6	97
Shale, gray, containing considerable minute fragments of carbonized plant remains, abundant muscovite and a little interbedded gray, sandy siltstone.		
Sandstone, very light-gray, very fine-grained, containing muscovite and minute fragments of carbonized plant remains.	16	118
Siltstone, gray, sandy, containing considerable muscovite and a few minute fragments of carbonized plant remains.	10	128
Shale, gray, containing considerable muscovite.	6	134
Coal, Brookville.	1	135
Claystone, light-gray, containing a few minute fragments of carbonized plant remains and a little muscovite.	3	138

Table 6.—Sample logs of wells—Continued

Sample log of well Bt-17—Continued

Description	Thickness in feet	Depth in feet
Homewood Formation		
Sandstone, gray, very fine-grained, silty, containing muscovite, minute carbonized plant remains, and a few siderite nodules.	34	172
Sandstone, very light-gray, very-fine to very coarse-grained.	37	209
Mercer Formation		
Shale, gray, silty, containing muscovite.	6	215
Sandstone, light-gray, very fine- to coarse grained, containing muscovite	4	219
Claystone, brownish-gray; interbedded silty shale, containing muscovite, pyrite and siderite nodules.	3	222
Sandstone, very light-gray, very fine; interbedded gray silty shale.	8	230
Claystone, very light-gray, containing abundant pyrite and a few minute fragments of carbonized plant remains.	2	232
Sandstone, gray, fine-grained, silty, containing muscovite, minute fragments of carbonized plant remains, and siderite nodules.	7	239
Shale, dark-gray, silty, containing considerable muscovite.	8	247
Coal.	1	248
Sandstone, gray, very fine- to fine-grained, silty, containing many minute fragments of carbonized plant remains and a little muscovite.	8	256
Siltstone, gray, sandy, containing many carbonized plant remains and a little muscovite.	5	261
Shale, gray and brown, containing considerable muscovite and pyrite.	28	289
Connoquenessing Formation, upper member		
Sandstone, light-gray, very fine- to fine-grained silty, containing muscovite and a few very coarse very light-gray quartz grains.	6	295
Sandstone, light-gray, very fine-to medium-grained, containing muscovite and a few coarse quartz grains.	7	302
Sandstone, light-gray, very fine- to coarse-grained.	7	309
Connoquenessing Formation, middle member		
Coal, Quakertown.	1	310
Connoquenessing Formation, lower member		
Sandstone, clear, very fine- to fine-grained, containing muscovite, siderite nodules, and carbonized plant remains.	13	323
Sandstone, clear, very fine- to medium-grained, argillaceous, containing muscovite, and a few coarse quartz grains; 4 feet of light-gray silty shale at base.	20	343
Sandstone, very light-gray, very fine- to medium-grained, argillaceous.	8	351
Sandstone, clear, very fine- to coarse-grained, argillaceous.	9	360

Table 6.—Sample logs of wells—Continued

Sample log of well Bt-17—Continued

Description	Thickness in feet	Depth in feet
Mississippian System		
Burgoon Sandstone		
Siltstone, gray, sandy, containing siderite nodules and a little muscovite.	4	364
Sandstone, clear, very fine- to medium-grained, argillaceous, containing a little muscovite and a few siderite nodules.	27	391
Sandstone, very light greenish-gray, very fine- to fine-grained, silty, containing considerable muscovite.	1	392
Sandstone, clear, very fine- to medium-grained, argillaceous, containing a little muscovite and a few siderite nodules.	32	424
Siltstone, gray to brownish-gray, containing muscovite; interbedded light-gray shale.	2	426
Sandstone, clear, very fine- to medium-grained, argillaceous, containing many siderite nodules and a little muscovite and pyrite.	11	437
Sandstone, light greenish-gray to gray, very fine- to very coarse-grained, argillaceous, containing minute fragments of carbonized plaint remains, pyrite, and a little muscovite.	4	441
Hempfield Shale		
Shale, gray to grayish-brown, containing a little muscovite and pyrite; interbedded gray to grayish-brown siltstone; a small amount of very fine- to medium-grained, light-gray sandstone.	6	447
Siltstone, gray, containing a little pyrite and minute fragments of carbonized plant remains; interbedded grayish-brown to dark-gray shale; a little very light-gray to gray, very fine- to coarse-grained sandstone.	5	452
Shale, gray to brownish-gray, silty, containing pyrite and minute fragments of carbonized plant remains	6	458
Sandstone, light-gray to gray, very fine- to fine-grained, containing a little pyrite.	3	461
Shale, dark-brown and gray, silty, containing a little muscovite and a little pyrite.	11	472
Sandstone, light-gray to gray, very fine- to fine-grained, containing a little muscovite and a little pyrite.	4	476
Shale, gray and brown, silty, containing muscovite, pyrite, and minute fragments of carbonized plant remains.	11	487
Shenango Formation		
Sandstone, very light-gray, very fine- to coarse-grained, argillaceous, and calcareous.	2	489
Sandstone, greenish-gray, very fine- to fine-grained, argillaceous, containing considerable muscovite and a little biotite.	8	497
Shale, gray, silty, containing considerable muscovite and minute fragments of carbonized plant remains.	3	500
Sandstone, very light-gray, very fine- to fine-grained, containing muscovite, a little pyrite, and minute fragments of carbonized plant remains.	3	503
Siltstone, gray, sandy, containing muscovite and minute fragments of carbonized plant remains.	10	513
Sandstone, light-gray to greenish-gray, very fine, silty, containing muscovite and minute fragments of carbonized plant remains.	7	520

Table 6.—Sample logs of wells—Continued

Sample log of well Bt-19

Description	Thickness in feet	Depth in feet
Pennsylvania System		
Homewood Formation		
Sample missing.	85	85
Sandstone, medium- to coarse-grained; loosely cemented; coal.	10	95
Sandstone, fine- to medium-grained, some grains show crystal faces.	5	100
Sandstone, medium- to coarse-grained.	7	107
Sandstone, fine-grained.	4	111
Mercer Formation		
Sandstone, medium-grained, clayey; interbedded siltstone and coal.	9	120
Sandstone, coarse-grained, clayey; interbedded siltstone.	8	128
Siltstone, dark gray to dark red; limonite and clay cement on grains.	6	134
Sandstone, very fine- to fine-grained.	10	144
Siltstone, dark gray; coal.	5	149
Siltstone, dark gray.	13	162
Connoquenessing Formation, upper member		
Sandstone, fine-grained.	21	183
Sandstone, medium- to coarse-grained, loosely cemented.	7	190
Connoquenessing Formation, middle member		
Siltstone, gray.	10	200
Connoquenessing Formation, lower member		
Sandstone, fine-grained, loosely cemented.	30	230
Mississippian System		
Burgoon Sandstone		
Sandstone, fine-grained; abundant dark-red and white siltstone.	32	262
Sandstone, fine-grained, loosely cemented; a little black shale or poor coal.	9	271
Sandstone, fine-grained, loosely cemented.	8	279
Sandstone, medium-grained.	6	285
Sandstone, medium-grained, loosely cemented.	6	291
Sandstone, very fine- to coarse-grained, loosely cemented.	7	298
Sandstone, medium-grained.	7	305
Sandstone, very fine- to medium-grained; interbedded siltstone.	20	325
Sandstone, very fine-grained; much gray siltstone.	15	340
Hempfield Shale		
Siltstone, dark-gray; small amount of coal.	7	347
Siltstone, dark-gray.	6	353
Sandstone, fine-grained.	9	362
Siltstone, gray; interbedded very fine- to fine-grained sandstone.	39	401
Shenango Formation		
Sandstone, very fine- to medium-grained; interbedded siltstone near bottom.	41	442
Siltstone, gray.	10	452
Sandstone, very fine- to fine-grained.	13	465
Siltstone, gray.	15	480
Sandstone, fine-grained; abundant gray siltstone.	24	504

Table 6.—Sample logs of wells—Continued

Sample log of well Bt-158

Samples described by: C. R. Fettke (1949)
Correlation by: C. W. Poth

Description	Thickness in feet	Depth in feet
Quaternary System		
Kent ground moraine		
Sand and gravel, pebbles consist mostly of sandstone	28	28
Pennsylvanian System		
Vanport Limestone		
Limestone, brownish-gray, very fine, dense	28	56
Clarion Formation		
Shale, dark-gray, silty; a little interbedded coal.	1	57
Sandstone, light-gray, in part stained yellowish brown by weathering, fine-grained, containing muscovite.	23	80
Coal, bony.	1	81
Homewood Formation		
Shale, gray, sandy, containing some muscovite.	19	100
Shale, very dark-gray, silty, containing muscovite and minute fragments of carbonized plant remains.	10	110
Mercer Formation		
Shale, black.	5	115
Shale, dark-gray.	7	122
Shale, gray, sandy, containing muscovite and minute fragments of carbonized plant remains.	3	125
Shale, very dark-gray; interbedded coal and gray claystone.	6	131
Shale, gray to dark-gray, sandy, containing muscovite and minute fragments of carbonized plant remains.	8	139
Shale, dark-gray.	9	148
Shale, dark-gray to grayish-black.	3	151
Shale, dark-gray, silty.	14	165
Sandstone, light-gray, fine-grained; a little interbedded black shale and coal.	4	169
Shale, dark-gray, silty, containing minute fragments of carbonized plant remains; interbedded, fine-grained, light gray sandstone.	15	184
Shale, very dark-gray, silty, containing muscovite and minute fragments of carbonized plant remains.	12	196
Sandstone, light-gray, fine-grained, containing a little muscovite.	11	207
Shale, dark-gray, silty, containing muscovite and minute fragments of carbonized plant remains.	10	217
Shale, dark-gray, silty; a little interbedded coal.	6	223
Claystone, dark grayish-brown.	5	228
Connoquenessing Formation, upper member		
Sandstone, brownish-gray, medium-grained; interbedded dark-gray, silty shale.	5	233
Sandstone, light-gray, medium-grained, poorly sorted, containing well-rounded quartz grains.	6	239

Table 6.—Sample logs of wells—Continued

Sample log of well Bt-158—Continued

Description	Thickness in feet	Depth in feet
Connoquenessing Formation, middle member		
Shale, dark-gray, silty, containing muscovite.	13	252
Connoquenessing Formation, lower member		
Sandstone, light-gray, fine-grained, containing muscovite.	18	270
Sandstone, light-gray, fine- to medium-grained, containing a little muscovite.	37	307
Sandstone, light-gray, very fine to fine-grained, containing a little muscovite.	23	330
Mississippian System		
Burgoon Sandstone		
Sandstone, light-gray, fine- to medium-grained, friable; interbedded dark-gray, silty shale.	6	336
Sandstone, light-gray, fine- to medium-grained, containing some muscovite.	7	343
Sandstone, light-gray, fine- to medium-grained, containing some muscovite and minute fragments of carbonized plant remains; interbedded dark-gray, silty shale.	7	350
Sandstone, light-gray, fine-grained, containing a little moscovite.	18	368
Sandstone, light greenish-gray, fine-grained, containing muscovite.	25	393
Hempfield Shale		
Shale, dark greenish-gray, silty; interbedded greenish-gray siltstone, containing muscovite and minute fragments of carbonized plant remains.	51	444
Shenango Formation		
Sandstone, light greenish-gray, very fine- to fine-grained, moderately friable, containing biotite and muscovite, and minute fragments of carbonized plant remains.	17	461
Shale, greenish-gray, silty; interbedded, very fine-grained, light greenish-gray sandstone, containing muscovite and minute fragments of carbonized plant remains.	13	474
Sandstone, light greenish-gray, very fine- to fine-grained, containing muscovite and minute fragments of carbonized plant remains.	19	493
Sandstone, light greenish-gray, fine-grained, containing a little muscovite.	23	516
Sandstone, light-gray, fine-grained.	17	533
Shale, dark-gray; interbedded very fine-grained, greenish-gray sandstone.	8	541
Sandstone, light greenish-gray, fine-grained, poorly sorted, containing muscovite.	9	550
Sandstone, light greenish-gray, very fine-grained; interbedded dark-gray shale.	7	557
Shale, dark greenish-gray, silty.	39	596

Table 6.—Sample logs of wells—Continued

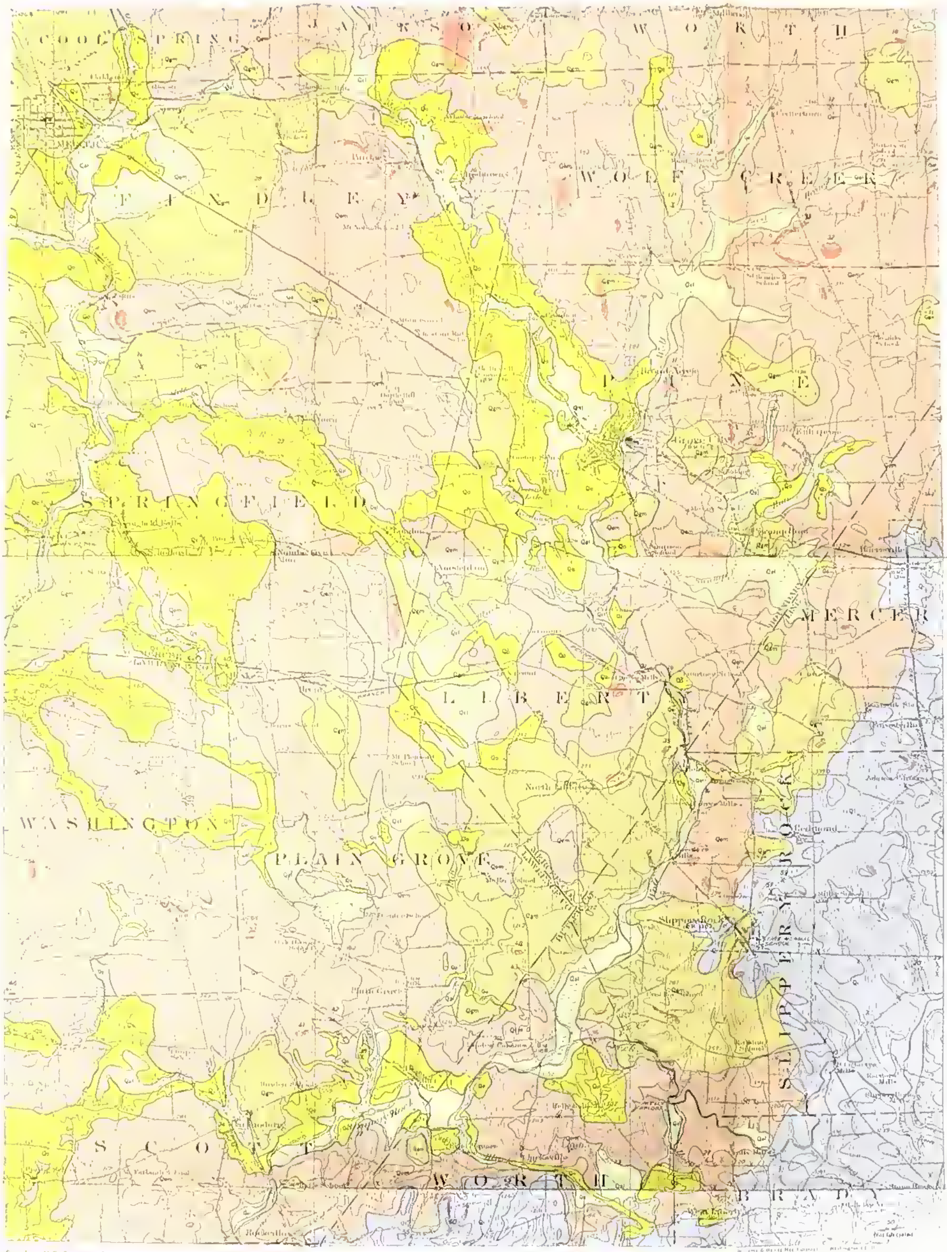
Sample log of well Mr-1184

Description	Thickness in feet	Depth in feet
Quaternary System		
Kent end moraine		
Sample missing.	29	29
Gravel, consisting predominantly of gray siltstone, limestone, black chert, and siderite; occasional pieces of red or black siltstone; very fine- to fine-grained sandstone, and iron stained pebbles; coarse sand.	3	32
Sample missing.	11	43
Pennsylvanian System		
Mercer Formation		
Coal.	3	46
Siltstone, gray to white, micaceous; very fine-grained sandstone, also micaceous.	4	50
Siltstone, gray to orange-brown, micaceous, pyritic.	4	54
Mudstone, gray; very minor amounts of gray siltstone and white, very fine-grained sandstone, which becomes more abundant downward.	10	64
Siltstone, dark-gray, carbonaceous streaks.	18	82
Mudstone, dark-gray, silty; light-gray siltstone near bottom.	9	91
Siltstone, gray; minor amounts of black shale.	12	103
Connoquenessing Formation, upper member		
Sandstone, white to orange, fine to medium-grained, loosely cemented.	19	122
Connoquenessing Formation, middle member		
Shale, black.	6	128
Coal.	2	130
Mudstone, dark-gray to black; some light-gray siltstone and very fine- to fine-grained sandstone.	12	142
Sample missing.	3	145
Mudstone, gray, leaf imprint on one piece.	5	150
Sample missing.	9	159
Connoquenessing Formation, lower member		
Sandstone, white, fine-grained, loosely cemented in upper part.	34	193
Mississippian System		
Hempfield Shale		
Mudstone, gray to tan; abundant siltstone pebbles.	6	199
Sandstone, white, very fine-grained.	6	205
Siltstone, gray, clayey near top.	12	217
Sandstone, white to gray, fine-grained.	6	223
Siltstone, gray and tan.	41	264
Shenango Formation		
Sandstone, gray to white, very fine- to fine-grained.	11	275

Table 6.—Sample logs of wells—Concluded

Sample log of well Mr-1185

Description	Thickness in feet	Depth in feet
Mississippian System		
Hempfield Shale		
Sample missing.	19	19
Mudstone, mottled orange and gray.	18	37
Siltstone, gray and tan.	11	48
Mudstone, gray.	27	75
Siltstone.	6	81
Mudstone.	19	100
Siltstone, gray and tan; minor amount of very fine-grained white sandstone.	5	105
Claystone, gray, well indurated.	5	110
Siltstone, gray; interbedded mudstone and fine- to medium-grained sandstone.	41	151
Shenango Formation		
Sandstone, white, medium-grained.	6	157
Sample missing.	12	169
Sandstone, white with some orange staining, very fine-to medium-grained, loosely cemented.	6	175
Mudstone, gray.	3	178
Sample missing.	2	180
Sandstone, white with some orange staining, fine-grained, loosely cemented; interbedded gray siltstone.	23	203
Siltstone, gray.	2	205



EXPLANATION

Qal

RECENT ALLUVIUM

Flood plains and kettles; silt and other alluvium on valley floors. Reported yields of wells range from 5 to more than 20 gpm.

Qem

KENT END MORAINE

Sandy, silty till; may have included gravel masses; 25 to more than 100 feet thick. Reported yields of wells range from 10 to 18 gpm with negligible drawdown.

Qgm

KENT GROUND MORAINE

Sandy, silty till, moderately to very pebbly, usually less than 25 feet thick. Water-bearing properties unknown.

Qo

KENT GLACIOFLUVIAL DEPOSITS

Sand and gravel in kames, outwash terraces, and eskers, in places more than 100 feet thick. Reported yields of wells range from 10 to 20 gpm.

Ql

ILLINOIAN TILL

Strongly weathered till; thin and discontinuous. Unimportant as source of water.

x ^{17}

Bedrock exposure. Numbered exposures referred to in text.

Coal strip mine. Numbered mines referred to in text.

Limit of glaciation

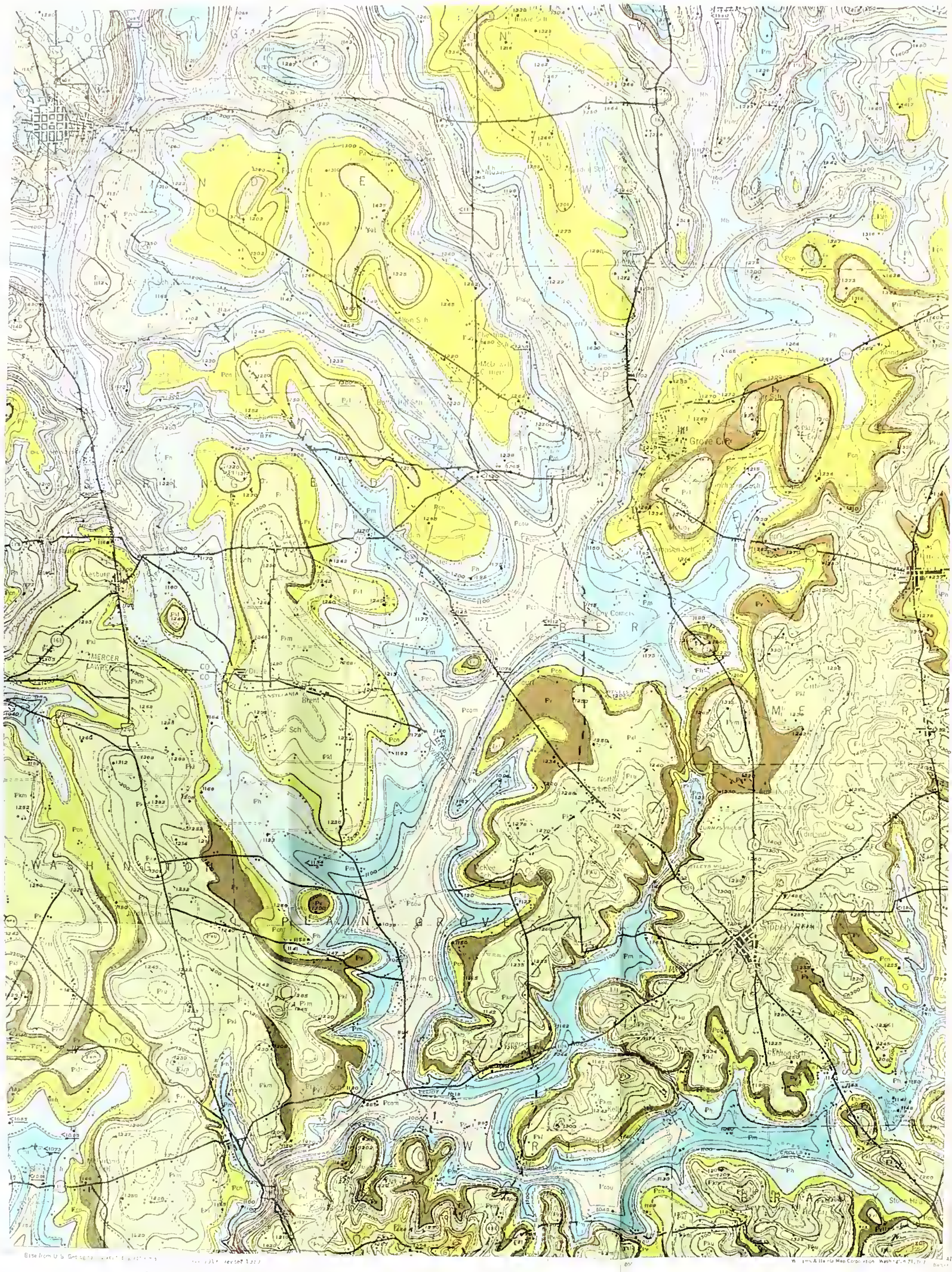
Base from U. S. Geological Survey
15' Topographic Quadrangle, 1913.

MAP SHOWING GLACIAL DEPOSITS AND THE LOCATION OF BEDROCK EXPOSURES IN THE MERCER QUADRANGLE

Glacial Geology by R. F. Sitler, 1957
Bedrock exposures located by C. W. Poth, 1961

SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



Base from U. S. Geological Survey

Williams & Heintz Map Corporation, Washington 27, D. C.

BEDROCK GEOLOGIC MAP OF THE MERCER QUADRANGLE, PENNSYLVANIA

Showing distribution of formations beneath glacial cover and outside the glacial border

Geology by C. W. Poth, 1961

Scale 1:48,000

1 ½ 0 1 2 Miles

Contour interval 20 feet

EXPLANATION

PENNSYLVANIAN

Allegheny Group

Pfu
Pfl

Freeport Formation

The upper member, Pfu, is composed chiefly of claystone but includes a thin limestone, and clayey, silty, thin-bedded sandstones near the top and bottom; the lower member, Pfl, is composed of the lower Freeport coal and shale. The formation is of small areal extent and is unimportant as a source of ground water.

Pku
Pkm
Pkl

Kittanning Formation

The upper member, Pku, is composed of the upper Kittanning coal, sandy shale, and clayey, silty sandstone; the middle member, Pkm, is composed of the middle Kittanning coal and clayey to sandy shale; the lower member, Pkl, is composed of the lower Kittanning coal, clayey shale, and thick, coarse-grained channel sandstone. Reported yields of wells range from 6 to 50 gpm. The total hardness of the water ranges from 185 to 460 ppm, and the iron content ranges from 1.1 to 11 ppm.

Pv

Vanport Limestone

A light gray dense limestone throughout much of quadrangle, cut out locally by channel sandstones of the Kittanning Formation. In the northwestern part of area it grades into silty or sandy limestone less than 1 foot thick. It is an excellent marker bed. Reported yields of wells range from 14 to 30 gpm. The single sample of water analyzed had a total hardness of 612 ppm and iron content of 6.8 ppm.

Pcn

Clarion Formation

Clayey to sandy shale, channel sandstones in the southern and eastern parts of the quadrangle. Two coals are present: the Scrubgrass coal, near the top of the formation, and the Brookville coal and its underclay at the base of the formation. Reported yields of wells range from less than 5 to 142 gpm. The total hardness of the water ranges from 170 to 342 ppm and the iron content ranges from 0 to 3 ppm.

Pottsville Group

Ph

Homewood Formation

Medium- to coarse-grained, loosely cemented sandstone which may be shaly near the top. In the east-central part of the quadrangle the formation is shale that contains thin beds of sandstone and, in some places, one or more coals. It is the major bedrock aquifer. Reported yields of wells range from 6 gpm to 30 gpm with little drawdown. The total hardness of the water ranges from 64 to 1,267 ppm and the iron content from 0.05 to 33 ppm.

Pm

Mercer Formation

Shale containing thin beds of sandstone, two or three coals, and two thin limestones, any of which may be absent locally. Reported yields of wells range from 2½ to 125 gpm. The total hardness of the water ranges from 102 to 524 ppm and the iron content from 0.3 to 8.5 ppm.

Pcu
Pcm
Pcl

Connoquenessing Formation

The upper member, Pcu, and the lower member, Pcl, are composed of medium-grained, well-cemented sandstone; the middle member, Pcm, is composed chiefly of shale but contains thin beds of sandstone and a coal. The sandstone members may thicken at the expense of the middle member and may also extend upward to the Homewood Formation. Reported yields of wells range from 3 to 40 gpm with negligible drawdown. The total hardness of the water ranges from 67 to 310 ppm and the iron content from 0 to 7.3 ppm.

Ps

Sharon Formation

Sandstone and an overlying shale unit. It is restricted to the extreme northwest corner of the quadrangle and is unimportant as a source of ground water.

MISSISSIPPIAN

Mb

Burgoon Sandstone

Sandstone in the southeastern part of the quadrangle; the upper part of the formation becomes shaly northward. The formation thins northward and westward and is absent from the northern part of the quadrangle. Hydrologic data are available only from wells in the Grove City area, which yield 1,000 gpm with 16 feet drawdown. The total hardness of this water ranges from 121 to 176 ppm and the iron content ranges from 0.06 to 1.7 ppm.

Mh

Hempfield Shale

Sandy to silty shale and fine-grained sandstone. Data are available from only one well which has a yield of 3 gpm. The water has a total hardness of 58 ppm and an iron content of 2.2 ppm.

Ms

Shenango Formation

Sandstone and interbedded shale in the northwestern part of the quadrangle, becoming more sandy southeastward. Its water is probably saline except in the north.

Geologic contact
dashed where covered.

1251

Selected well or outcrop showing
elevation of bedrock surface.

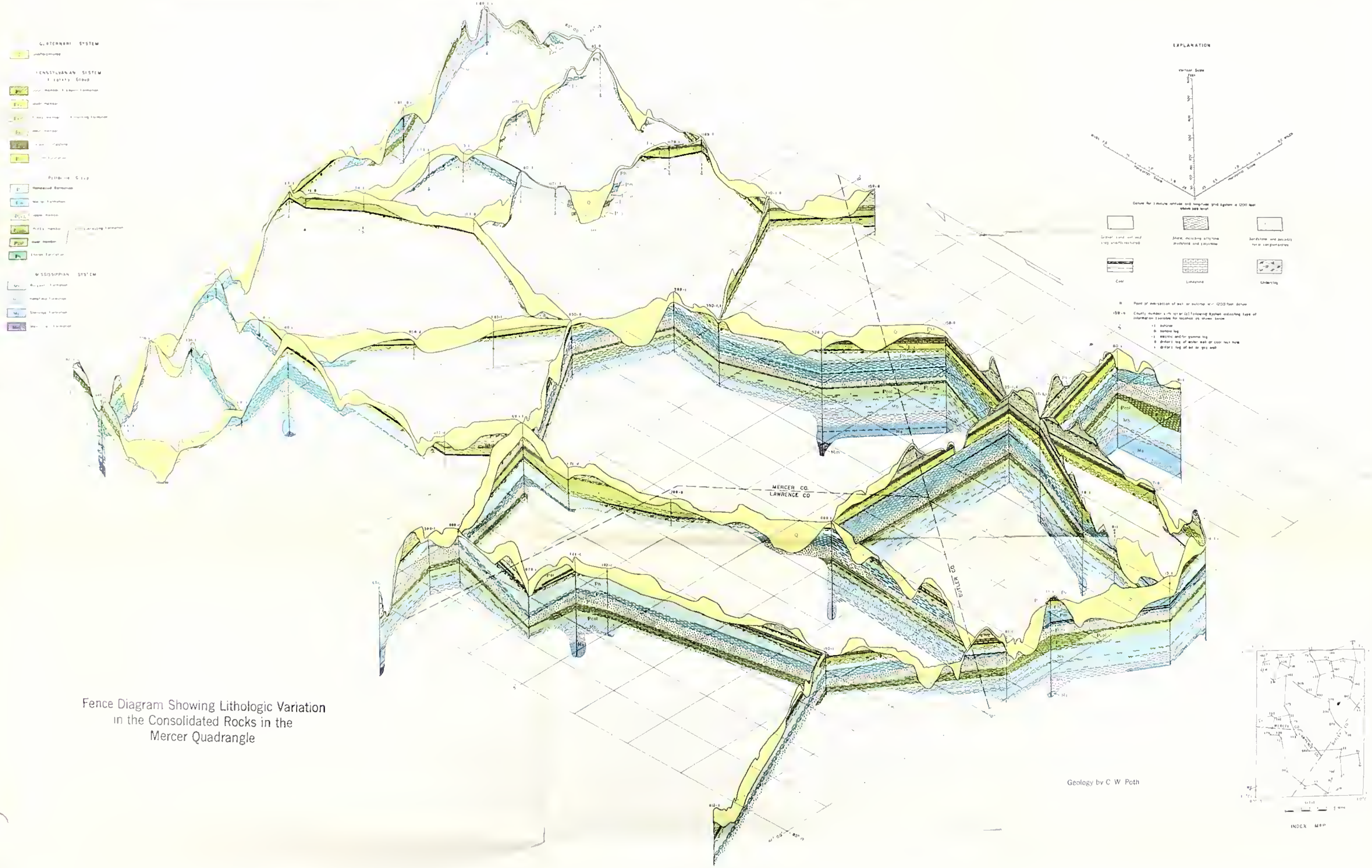
<1272

Selected well that did not reach bedrock
showing elevation of bottom of well

1200

Contour drawn on bedrock surface

Commonwealth of Pennsylvania
Department of Internal Affairs
Genevieve Blatt, Secretary
Topographic and Geologic Survey
Arthur A. Socolow, State Geologist

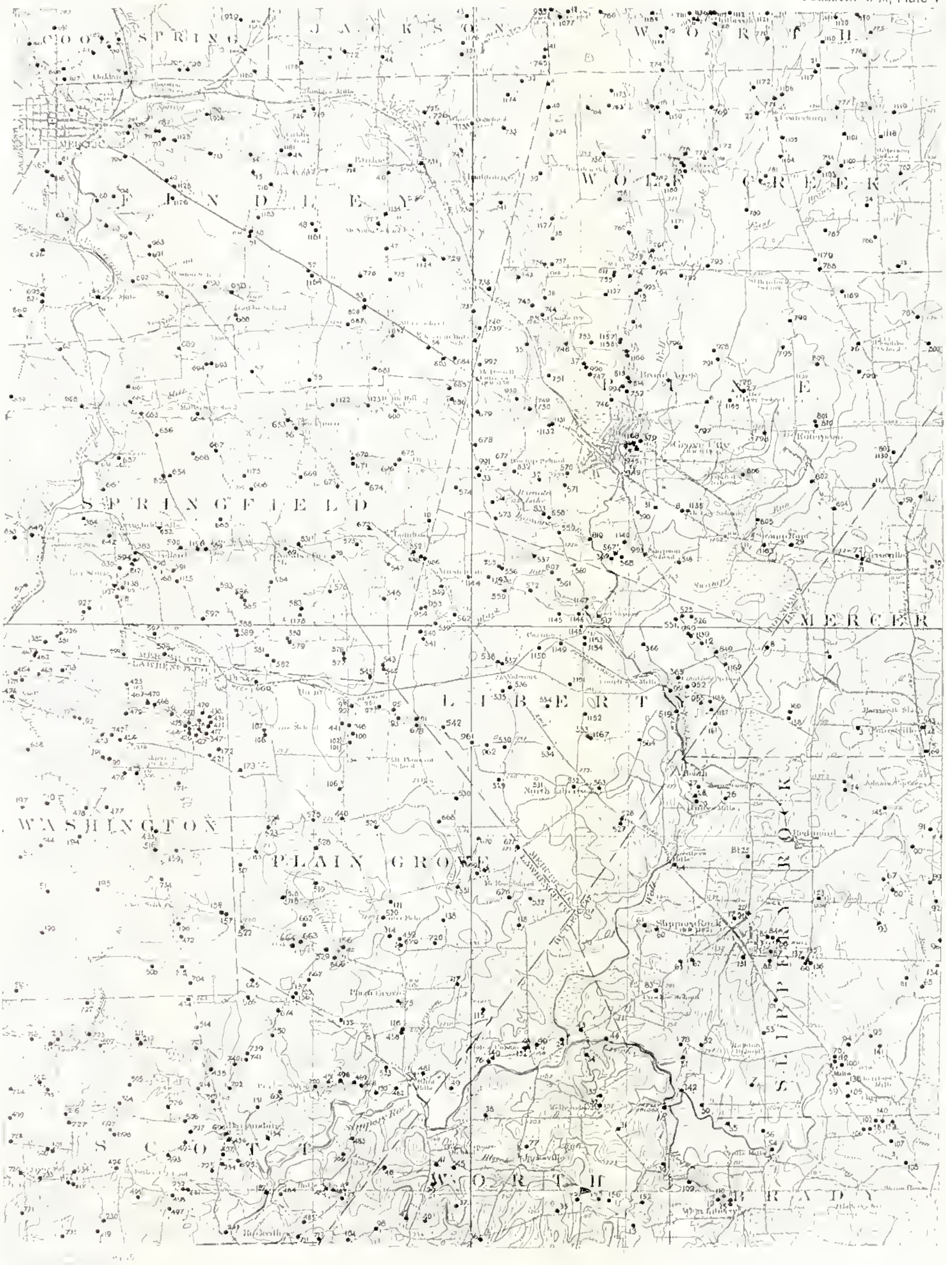


Fence Diagram Showing Lithologic Variation in the Consolidated Rocks in the Mercer Quadrangle

Geology by C W Poth

PENNSYLVANIA GEOLOGICAL SURVEY

BULLETIN W 16, Plate 4



MAP SHOWING LOCATION OF WELLS IN THE MERCER QUADRANGLE

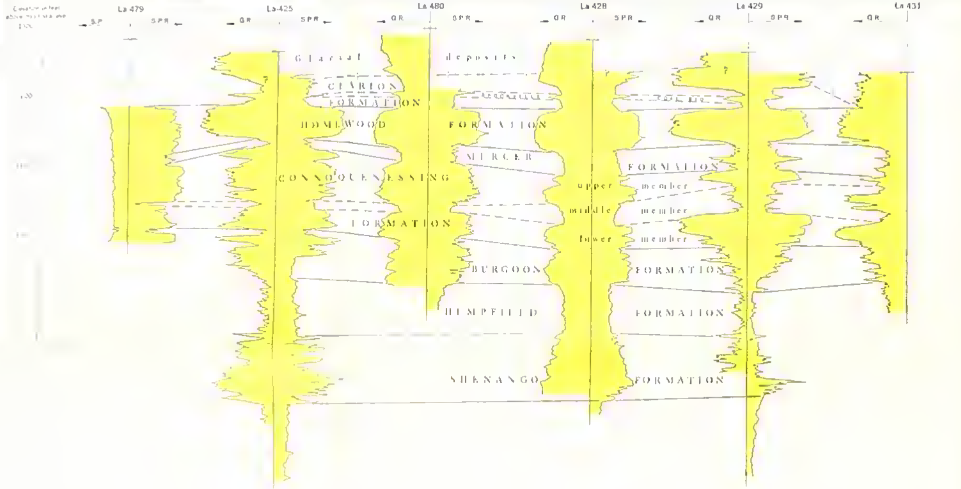


Figure A. Correlation of stratigraphic units in wells La-479, La-425, La-480, La-428, La-429, and La-431.

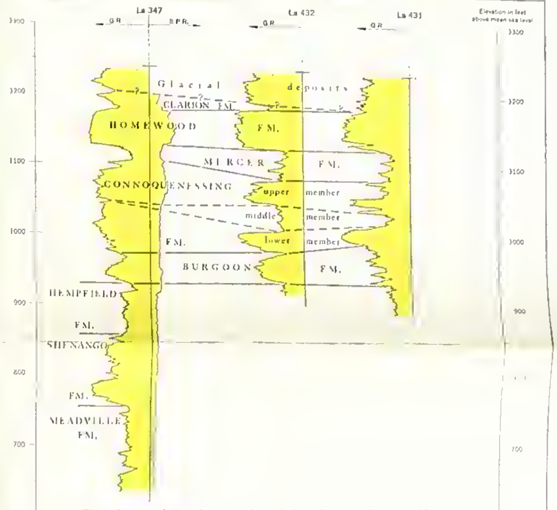


Figure B. Correlation of stratigraphic units in wells La-347, La-432, and La-431.

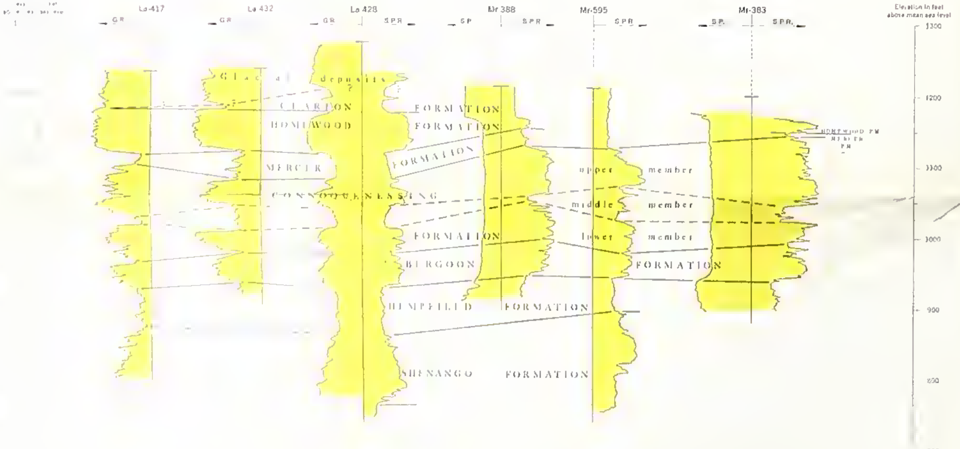


Figure C. Correlation of stratigraphic units in wells La-417, La-432, La-428, Mr-388, Mr-595, and Mr-383.

Key

S.P. – Selfpotential in millivolts

G.R. – Gamma Ray in milliroentgen/hour

S.P.R. – Single-point resistance in ohm-meters

Plate 5. Electric and gamma-ray logs of wells in the west-central part of the Mercer quadrangle.